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# Development of Mesoscale Air Quality Simulation Models. Volume 4 User's Guide to MESOGRID (Mesoscale Grid) Model

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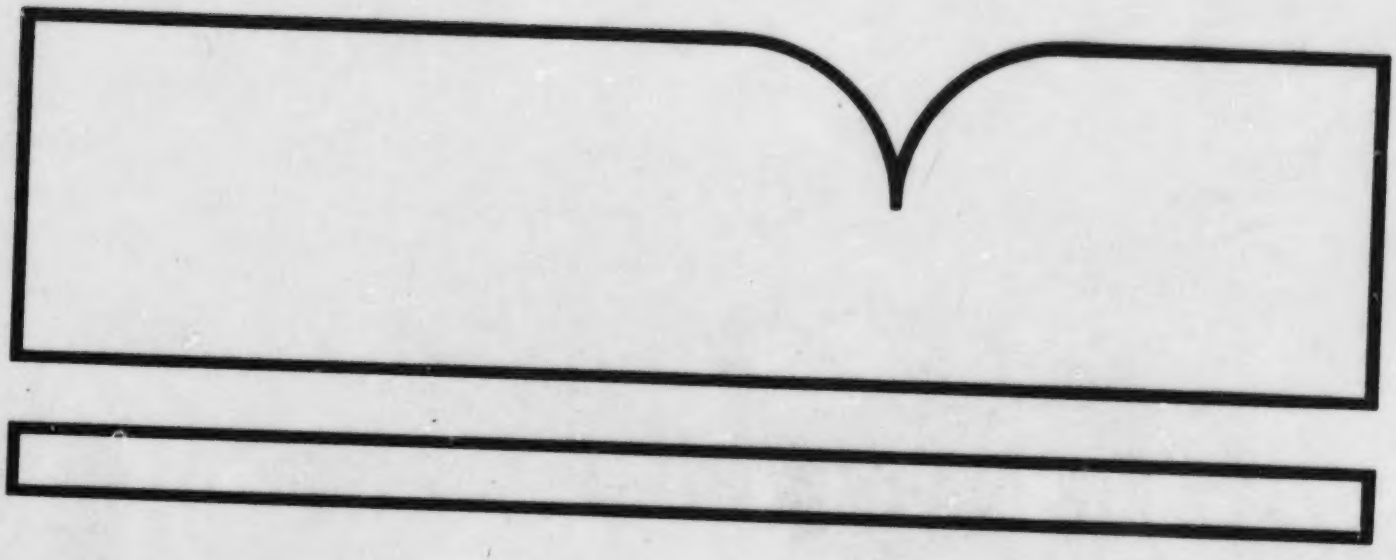

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# DEVELOPMENT OF MESOSCALE AIR QUALITY SIMULATION MODELS
# VOLUME 4. USER'S GUIDE TO MESOGRID (MESOSCALE GRID) MODEL

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16. Abstract (Limit: 200 words)

MESOGRID is a regional-scale grid model, based on the Egan-Mahoney method of moments, especially designed to simulate the air quality impacts of multiple sources at long transport distances. It has been developed to answer the need for a simple computationally practical, easy to use and flexible mesoscale grid model - suitable for decision-making and regulatory applications - particulatly at transport distances beyond the range of applicability of conventional straight-line Gaussian plume models. MESOGRID explicitly includes vertical diffusion; horizontal diffusion is included only through spatial and temporal variations in mesoscale meteorology.

Highly user-oriented, MESOGRID provides a range of flexible options, and its clean, modular structure permits further modifications with ease. It is designed to be driven by user-specified meteorological scenarios, of arbitrary duration, constructed by a suitable meteorological preprocessor model (e.g., MESOPAC). It outputs spatially-gridded concentration arrays averaged over arbitrary time intervals of one hour or more, and is designed to be coupled to a postprocessor model (e.g., MESOFILE) to provide additional graphical and statistical analyses. Routines are provided for: plume rise; fumigation; linear conversion of SO2 to SO4; and dry deposition of SO2 and SO4.

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# 1. INTRODUCTION

## 1.1 Background

In response to a growing national commitment to the use of indigenous coal reserves to meet energy generation demands, several regions of the country will experience greatly expanded use of coal and oil shale resources for steam electric power plants and other coal-based energy resource development. But, as mandated by federal National Ambient Air Quality Standards, and by the PSD major source review procedures, additional coal-based energy resource development (ERD) will only be permitted where consistent with the maintenance of human health, welfare, and environmental quality. Accordingly, the siting and generation capacity of such ERD facilities may be constrained by their potential impacts on regional ambient air quality.

Various plans have been proposed for regional development of multiple major new facilities, and suitable model simulation tools are needed to assess the impacts of different energy development scenarios on regional-scale air quality.

To meet this need in the public interest, the National Oceanic and Atmospheric Administration (NOAA) has sponsored a study by Environmental Research & Technology, Inc. (ERT) to develop, evaluate, and exercise a number of alternative approaches to regional-scale ambient air quality modeling. A major objective of this study is to provide a suite of air quality simulation models that are both technically sound and computationally practical for assessing regional-scale impacts of energy development scenarios.

As described in the companion report, Volume 1 (Bass et al. 1979), three different air quality transport-diffusion models have been developed, implemented and compared for simulation of point-source plume dispersion on the mesoscale [e.g., dispersion at ranges of 100 to 1,000 kilometers (km)]. The models are optimized for regional-scale impacts; ambient air concentrations calculated in the near field of sources, that is, less than 100 km, are not realistic.* Both worst-case and average dispersion situations are treated, with meteorological inputs constructed from rawinsonde data that is readily available for the region. The models are computationally practical for simulating the impact of multiple point sources over periods of several days to several weeks, and are easy to use for a variety of decision-making and regulatory applications. Finally, these models are intended to serve as flexible testbeds for further research, development and simulation tasks.

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*Subsequently, the MESOPUFF model has been augmented to provide realistic near-field impacts (see the companion report, Volume 3).

The three new models are, respectively:

- MESOPLUME, a mesoscale variable-trajectory Gaussian "plume-segment" model (Benkley and Bass 1979a), adapted by ERT from the plume segment approach taken in the STRAM model (Hales et al. 1977),

- MESOPUFF, a mesoscale variable-trajectory Gaussian "puff" superposition model (Benkley and Bass 1979b), adapted by ERT from the puff approach taken in the MESODIF model (Start and Wendell 1974); and

- MESOGRID, a mesoscale numerical grid model, adapted from the method of moments approach taken in the SULFA3D model (Egan et al. 1976).

This report, the fourth in a series entitled "Development of Mesoscale Air Quality Simulation Models", describes the MESOGRID model in technical detail; illustrates its application; and provides a User's Guide to the model. However, to obtain a fuller understanding of the model's capabilities, limitations and recommended usage, the user should be familiar with the relevant materials contained in the following related reports:

- the companion report (Volume 1) describing the extensive series of comparison and model sensitivity analyses performed with these models (Bass et al. 1979);

- the companion report describing the specially designed MESOSCALE meteorological preprocessor program, MESOPAC (Benkley and Bass, 1979c);

- the companion report (Volume 5) describing the specially designed model postprocessing and analysis system, MESOFILE (Scire et al. 1979).

## 1.2 The MESOSCALE Grid Model (MESOGRID)

MESOGRID is a hybrid Lagrangian-Eulerian advection-diffusion model for simulating the mass conservation equation. It is based on the Egan-Mahoney method of moments (Egan and Mahoney 1972) and has been adapted from the SULFA3D model originally developed by Rao (Egan et al. 1976). The model accounts for horizontal advective transport and vertical eddy diffusion, but no horizontal diffusion is included. At each time step, pollutant mass is advected and diffused in a Lagrangian sense; immediately afterwards, a mass decomposition to a stationary Eulerian grid is performed. The numerical method conserves the zeroth, first, and second moments of the pollutant mass distribution; this method minimizes pseudodiffusive errors associated with conventional finite-difference

approximations. Note that, as is true of any Eulerian grid model, the MESOGRID model will not conserve pollutant mass exactly in a divergent wind field. MESOGRID accommodates multiple sources and includes modules for plume rise, fumigation, linear conversion of sulfur dioxide ($SO_2$) to sulfate ($SO_4^=$), and dry deposition of $SO_2$ and $SO_4^=$.

## 1.3 Integrated Mesoscale Modeling System

The MESOGRID model has been incorporated as a fully-independent element within an efficient, easy to use integrated mesoscale modeling system, depicted in Figure 1-1, comprising meteorological preprocessing, mesoscale transport-diffusion, and post-processing components. The standardization of model input/output functions in this system facilitates, for example, the easy combination of results from two or more model runs, or the direct and cost-effective comparison of simulations performed with two or more different models (see, for example, Bass et al. 1979). The meteorology preprocessor MESOPAC drives identically any of the three mesoscale transport-diffusion models. Each of these models in turn identically communicates its results to the MESOFILE postprocessing system responsible for file management, display, and statistical analysis of all model output fields.

## 1.4 Organization of the Report

The remainder of this report is organized as follows: A detailed technical description of the MESOGRID model is contained in Section 2; specific user instructions are described in Section 3; a test case for the MESOGRID model is presented in Section 4. A complete Fortran listing of the MESOGRID model is appended to the document in microfiche form.

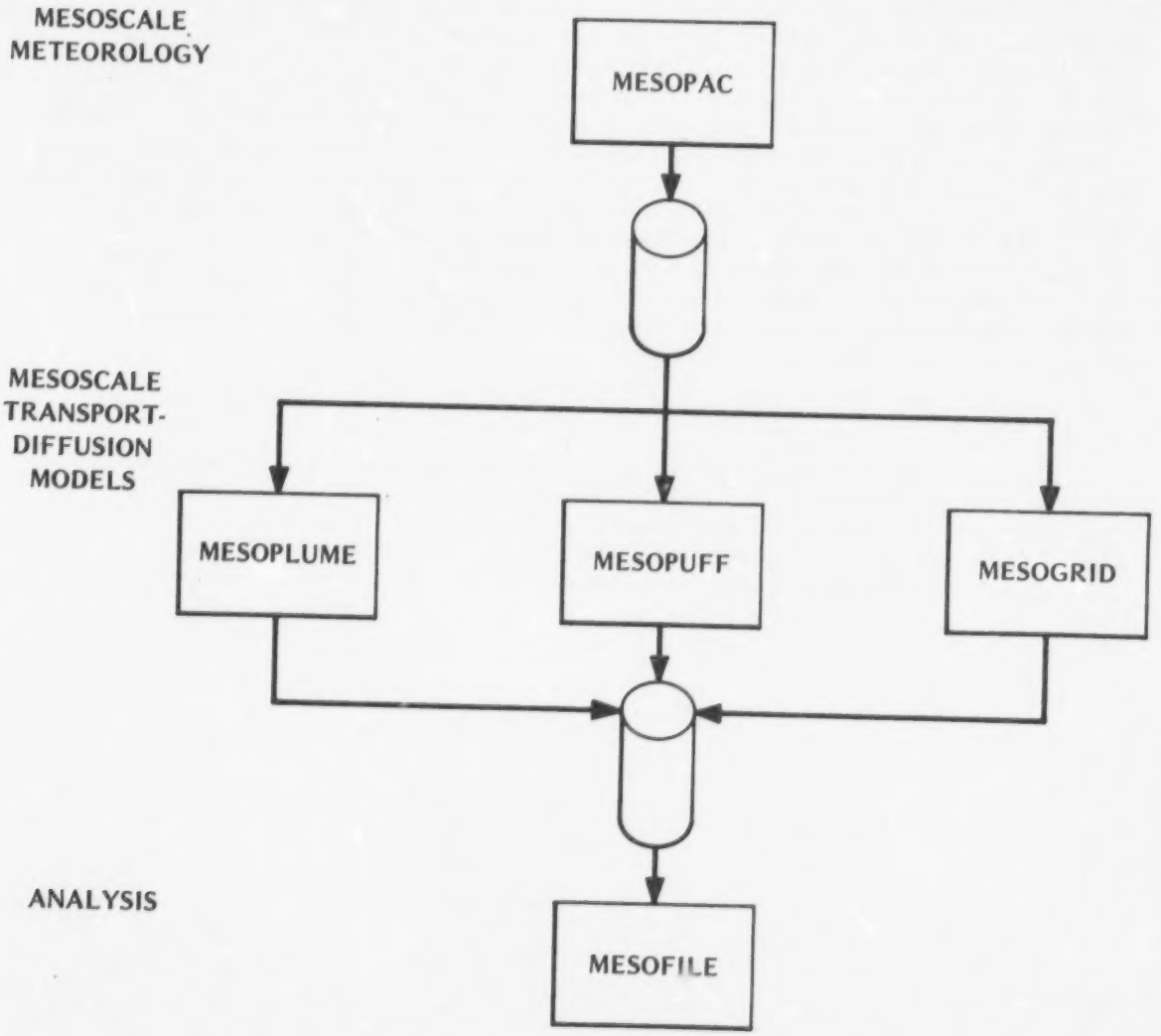


Figure 1-1 Integrated Modeling System

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# 2. MESOGRID TECHNICAL DISCUSSION

## 2.1 Model Formulation

The horizontal advection, vertical diffusion, linear decay, and dry deposition of sulfur dioxide ($SO_2$) and sulfate ($SO_4^=$) species on regional scales are represented in MESOGRID by a discrete-level numerical representation of the continuous equations describing the mass conservation of the respective pollutant species:

$$\frac{\partial C_1}{\partial t} = -u\frac{\partial C_1}{\partial x} - v\frac{\partial C_1}{\partial y} + \frac{\partial}{\partial z}\left(K_z\frac{\partial C_1}{\partial z}\right) - k_1 C_1 - f_1 C_1 \delta(z,H,\Delta z_k) + \frac{Q_1}{\Delta z_k} \qquad (2\text{-}1)$$

$$\frac{\partial C_2}{\partial t} = -u\frac{\partial C_2}{\partial x} - v\frac{\partial C_2}{\partial y} + \frac{\partial}{\partial z}\left(K_z\frac{\partial C_2}{\partial z}\right) + \frac{3}{2}k_1 C_1 - f_2 C_2 \delta(z,H,\Delta z_k) \qquad (2\text{-}2)$$

where

$x$ is the east-west horizontal coordinate (m);

$y$ is the north-south horizontal coordinate (m);

$z$ is the vertical coordinate (m);

$t$ is the time (s);

$C_1$, $C_2$ are the ambient concentrations of sulfur dioxide ($SO_2$) and sulfate ($SO_4^=$) respectively (g $m^{-3}$);

$Q_1$ is the source emission rate of $SO_2$ (g $m^{-2}$ $s^{-1}$) within a vertical cell of height $\Delta z_k$ (the $SO_4$ emission rate is assumed to be zero);

$u(x,y)$, $v(x,y)$ are, respectively, the x and y components of horizontal wind velocity (m $s^{-1}$);

$K_z$ is the vertical eddy diffusivity ($m^2$ $s^{-1}$);

$k_1$ is the rate ($s^{-1}$) of linear decay of $SO_2$ to $SO_4^=$;

$f_1$, $f_2$ are the dry deposition rate functions ($s^{-1}$) of $SO_2$ and $SO_4^=$, respectively. Dry deposition is considered only when the height z of a parcel of pollutant is below the mixing height H; and

$\delta(z,H,\Delta z_k) = 1$ for $z \leq H$ and $k = 1$; $\delta(z,H,\Delta z_k) = 0$ for $z > H$ or $k \neq 1$.

The set of equations used by MESOGRID invokes these important assumptions:

- the advective wind field is two-dimensional (horizontal) only; thus if the model is to conserve mass strictly, it must be driven by a horizontally nondivergent wind field.
- horizontal diffusion is negligible compared to advective transport.

The MESOGRID model solves the set of discretized advection-diffusion equations on a three-dimensional grid with either two or three vertical levels (as desired). The Egan-Mahoney (1972) method of moments is used to minimize pseudodiffusive errors by conservation of the lower order moments of the pollutant distribution. The grid cell resolution is user-specifiable (to a maximum of 26x26x3 cells). The horizontal grid size is uniform; the vertical cell dimensions may vary between levels. The choice of grid cell dimensions will reflect the following considerations:

1) the overall size of the area to be modeled, and required spatial resolution of concentration fields,
2) the advective and diffusive numerical stability criteria, and
3) the relative model execution costs as dictated by items 1 and 2 above.

## 2.2 The Grid System

MESOGRID is referenced to a simple Cartesian coordinate system for easy interaction with a variety of input/output (I/O) routines, as well as pre- and postprocessors. The MESOGRID grid cell system is illustrated in Figure 2-1. Each grid cell is denoted by an ordered triple of indices (i,j,k) where i is the east-west (x-direction) index (i=1 is the westernmost cell), j is the north-south (y-direction) index (j=1 is the southernmost cell), and k is the vertical (z-direction) index (k=1 is the lowest level). For example, the center of the southwesternmost and lowest grid cell (with indices 1,1,1) corresponds to the physical location ($x=0$, $y=0$, $z=\Delta z_1/2$). All emission source data and meteorological data input to the MESOGRID model are referenced to this grid system.

## 2.3 Specification of Model Inputs

The meteorological fields required to drive the MESOGRID model are generated by the MESOPAC model (Benkley and Bass 1979c), a meteorological preprocessing package developed specifically for this purpose. MESOPAC produces gridded hourly interpolated fields of:

- horizontal (u,v) wind components ($m\ s^{-1}$),

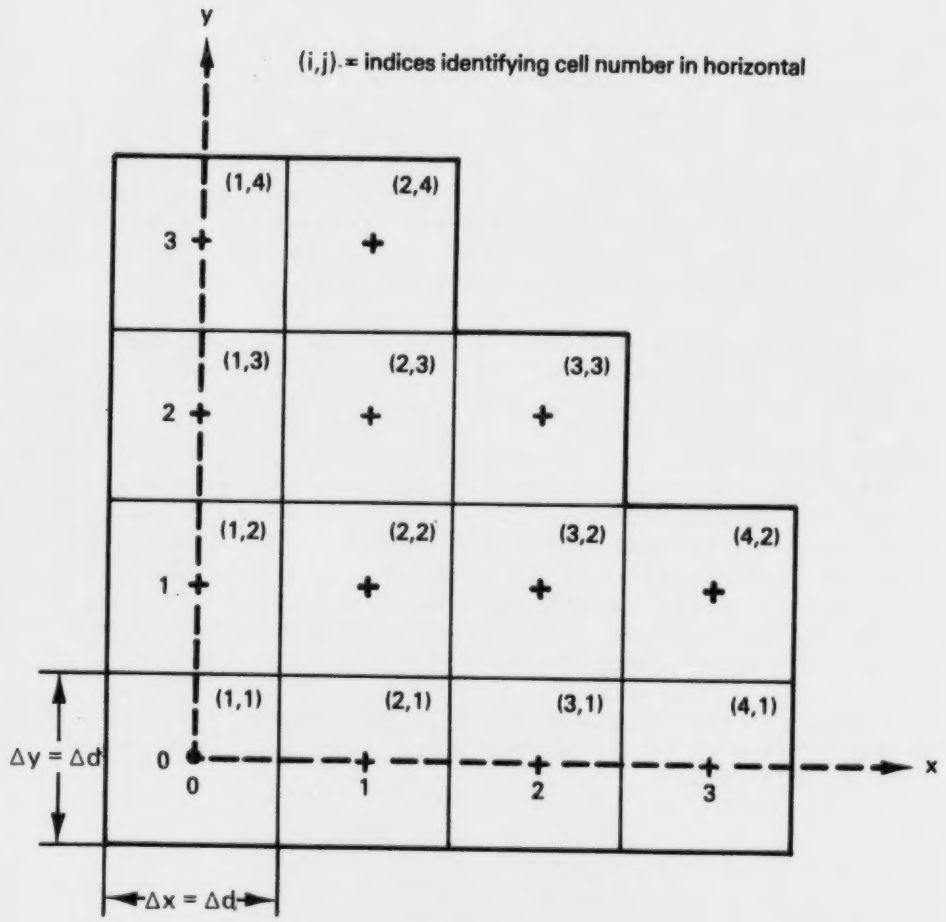


Figure 2-1 A Schematic Representation of the MESOGRID Cartesian Coordinate System

- mixing depth (m), and
- Pasquill-Gifford-Turner (PGT) stability class.

Interaction of the MESOGRID model with the MESOPAC preprocessor is straightforward-the coordinate system is identical in both models and the grid point values of meteorological variables produced by MESOPAC apply directly to the center of each MESOGRID cell. At present, the horizontal wind components generated by MESOPAC are treated as invariant with height, although the MESOGRID model itself can accommodate vertically layered wind fields. The mixing depth and stability fields are used by MESOGRID to determine eddy diffusivity ($K_z$) vertical profiles (see a detailed discussion in Section 2.4.3).

Emission source locations are user-specified through a three-dimensional Cartesian coordinate system (x,y,z coordinates), and MESOGRID assigns the appropriate (i,j,k) grid cell. For example (see Figure 2-1), a source with x,y coordinates (0.6, 1.4) is assumed to fall within a grid cell with horizontal indices (2,2). Acceptable ranges of x and y are ($-0.5 \leq x \leq i_{max} - 0.5$) and ($-0.5 \leq y \leq j_{max} - 0.5$); if x or y values are specified beyond those limits, a MESOGRID run will terminate with the error message SOURCE NOT IN GRID. Source locations are assigned vertical indices (k) as illustrated in Figure 2-2. Thus, a source with an effective release height, $h_e = h_s + h_p = 600$ m, where $h_s$ is the stack height and $h_p$ the plume rise (see Section 2.8), is assumed to fall within the second (k=2) vertical layer.

Point source emissions Q($g\ s^{-1}$) are assumed to be distributed uniformly throughout a grid cell; an equivalent volume emission source rate is defined by:

$$\overline{Q} = \frac{Q}{\Delta z_k (\Delta d)^2} \qquad (2\text{-}3)$$

where $\overline{Q}$ is the cell-averaged source emission rate ($g\ m^{-3} s^{-1}$), Q is the point-source emission rate ($g\ s^{-1}$), $\Delta z_k$ is the vertical depth (m) of the k-th cell, and $\Delta d$ is the size of a horizontal grid cell. As an example, if $Q = 10^3 (g\ s^{-1})$, $\Delta z_k = 10^3$ m, and $\Delta d = 4 \times 10^4$ m (typical values), then $\overline{Q} = 6.25 \times 10^{-10} (g\ m^{-3} s^{-1})$.

## 2.4 Solution of the Advection-Diffusion Equations

The tracer equations for each pollutant (Equations 2-1 and 2-2) are solved in finite difference representations. The solution proceeds in two sequential steps. In the first step, pollutant mass is advected by the wind field. Immediately thereafter, in the second step, pollutant mass is diffused in the vertical at a rate proportional to the layer values of the $K_z$ field. These computational steps are described next.

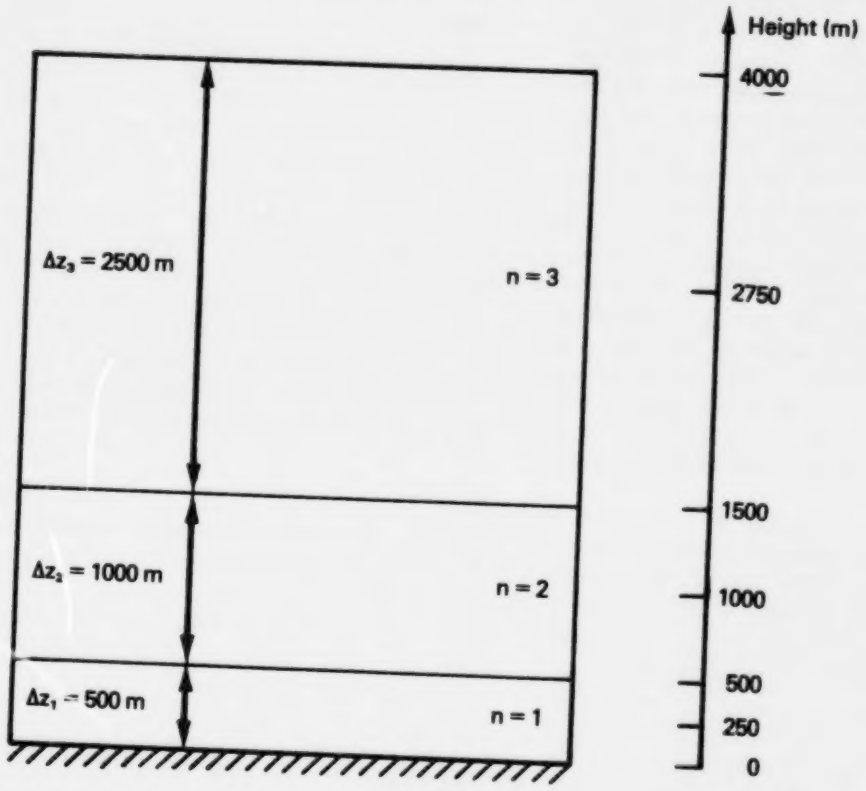


Figure 2-2 Vertical Structure of the MESOGRID Computation Grid Assuming Default Values

### 2.4.1 Horizontal Advection

Conventional finite-difference approximations to the two advection terms, $u\partial C/\partial x$ and $v\partial C/\partial y$ in Equations 2-1 and 2-2, produce truncation errors; these errors can introduce spurious, pseudodiffusive effects in the predicted concentration terms. This artificial diffusion by the numerical scheme can be, in some instances, orders of magnitude larger than that resulting from the real atmospheric mixing process. Various special finite-differencing methods have been proposed for control of numerical diffusion (e.g., SHASTA--see Boris and Book 1973). In the present model, the approach adopted is a unique mixture of both Eulerian and Lagrangian approaches, called the Method of Moments (Egan and Mahoney 1972). This method substantially reduces the pseudodiffusion associated with numerical advection term by using one or more statistical moments of the concentration distribution within a grid element scheme. This section describes this procedure in detail. To keep the explanation as simple as possible, the discussion of horizontal advection will be initially limited to the description of advection in the east-west direction only.

Defining C as the average concentration within a grid element, the forward-in-time, backward-in-space, finite-difference approximation to the horizontal advection for a uniform wind field $u > 0$ (neglecting diffusive, source, and sink terms) is

$$C_{m,k}^{T+1} = (1 - \sigma)\, C_{m,k}^{T} + \sigma C_{m-1,k}^{T} \qquad (2\text{-}4)$$

where T denotes the $T^{th}$ time step such that $t = T\Delta t$, m and k denote the $m^{th}$ ($i^{th}$ or $j^{th}$) horizontal and the $k^{th}$ vertical grid elements, and $\sigma = u\Delta t/\Delta d$, the ratio of the advection distance per unit time step to the grid element dimension. The Courant advective criterion stability requires that $\sigma \leq 1$. After many time steps, the resulting horizontal advection can be likened to advection with velocity u and upwind-downwind mixing with a pseudodiffusive coefficient of magnitude $u\Delta d(1 - \sigma)/2$. A substantial reduction in this diffusive effect can be achieved if the first and second moments of the material within a cell are calculated after each time step and used to adjust the amount of material advected downwind during the next time step. Specifically, the procedure calculates the first and second moments of the concentration distribution after material has been advected into and out of a grid cell. These moments are then used to define a simple rectangular concentration distribution in the grid cell having the same amount of total mass and identical first and second moments.

Suppose $\xi_m$ denotes the relative displacement of material within the $m^{th}$ cell from the center of the cell, such that $\xi_m$ ranges from -0.5 at the left hand to +0.5 at the right-hand extreme boundary of a cell. The

zeroth, first, and centered second moments of the grid cell concentration distributions, corresponding to the mean concentration, the center of mass, and the scaled distribution variance are given by

$$C_m = \int_{-0.5}^{0.5} C(\xi_m)\, d\xi_m$$

$$F_m = \int_{-0.5}^{0.5} C(\xi_m)\, \xi_m\, d\xi_m / C_m \qquad (2\text{-}5)$$

$$R_m^2 = \int_{-0.5}^{0.5} C(\xi_m)\, (\xi_m - F_m)^2\, d\xi_m / C_m$$

For simple rectangular concentration distributions, these integrals are readily evaluated by summation for each grid element in terms of the material distributions of the portions remaining and newly advected in after each successive time step. It may be seen that the nature of the downwind transfer depends on the value of the "portioning" parameter,

$$P_m = (F_m + \sigma + 0.5\, R_m - 0.5)/R_m \qquad (2\text{-}6)$$

For $P_m \leq 0$ none of the material is advected into the m+1 cell. If $P_m \geq 1$ all of the material is advected into the downwind cell. For $1 > P_m > 0$, an amount of material $P_m C_m$ is advected to the downwind cell, and $(1 - P_m)C_m$ remains in the $m^{th}$ cell. Considering now the general case for the $m^{th}$ cell with inflow from the m-1 cell, outflow to the m+1 cell, and continuous source addition during the time step, the forward-time computation procedure at grid element m can be represented as

$$C_m^{T+1} = C_r + C_a + \overline{Q_m}\Delta T$$

$$C_m^{T+1} F_m^{T+1} = C_r F_r + C_a F_a + \overline{Q_m}\Delta t(\sigma/2)$$

$$C_m^{T+1} (R^2)_m^{T+1} = C_r[R_r^2 + 12(F_m^{T+1} - F_r)^2] \qquad (2\text{-}7)$$

$$+ C_a[R_a^2 + 12(F_m^{T+1} - F_a)^2]$$

$$+ \overline{Q_m}\Delta t[1 + 12(F_m^{T+1} - \sigma/2)^2],$$

where subscripts r and a indicate quantities remaining and newly advected in, respectively. This procedure completely eliminates pseudo-diffusive effects for a simple rectangular concentration distribution. Small diffusive errors will remain when more complicated distributions are advected.

In the MESOGRID model, the scheme described above has been generalized to two-dimension horizontal advection. Figure 2-3 illustrates in top view the advection of a block of material with a uniform concentration distribution. In analogy to the one-dimensional advection procedure, one may define [suppressing the horizontal grid element subscripts (i,j)]

$$P_i = (F_i + \sigma_i + 0.5\ R_i - 0.5)/R_i$$

$$P_j = (F_j + \sigma_j + 0.5\ R_j - 0.5)/R_j \qquad (2\text{-}8)$$

Then (imagining a newly emitted parcel of material contained within one grid cell), for the case illustrated in Figure 2-3, where $0 < P_i$, $P_j < 1$, the contribution to the new concentrations at each of the four grid cells sharing the material after advection is

$$C^{T+1}_{i+1,j} = C^T_{i,j}\ P_i(1 - P_j),$$

$$C^{T+1}_{i,j+1} = C^T_{i,j}(1 - P_i)P_j,$$

$$C^{T+1}_{i+1,j+1} = C^T_{i,j}\ P_iP_j, \qquad (2\text{-}9)$$

$$C^{T+1}_{i,j} = C^T_{i,j}(1 - P_i)(1 - P_j).$$

The rules for advection for $P < 0$ or $P > 1$ follow those derived for one-dimensional advection, as do the expressions for calculating the first and second moments. In general the moments are evaluated from the concentration distributions advected into a cell from more than one adjacent cell. The computation procedure determines which neighboring cells contribute to the moment calculations and computes $\Sigma C_m$, $\Sigma C_m F_m$, $\Sigma C_m R_m^2$, and then the new values for each element:

$$C^{T+1} = \Sigma C_m \qquad (2\text{-}10)$$

$$F^{T+1} = \frac{\Sigma C_m F_m}{C^{T+1}} \qquad (2\text{-}11)$$

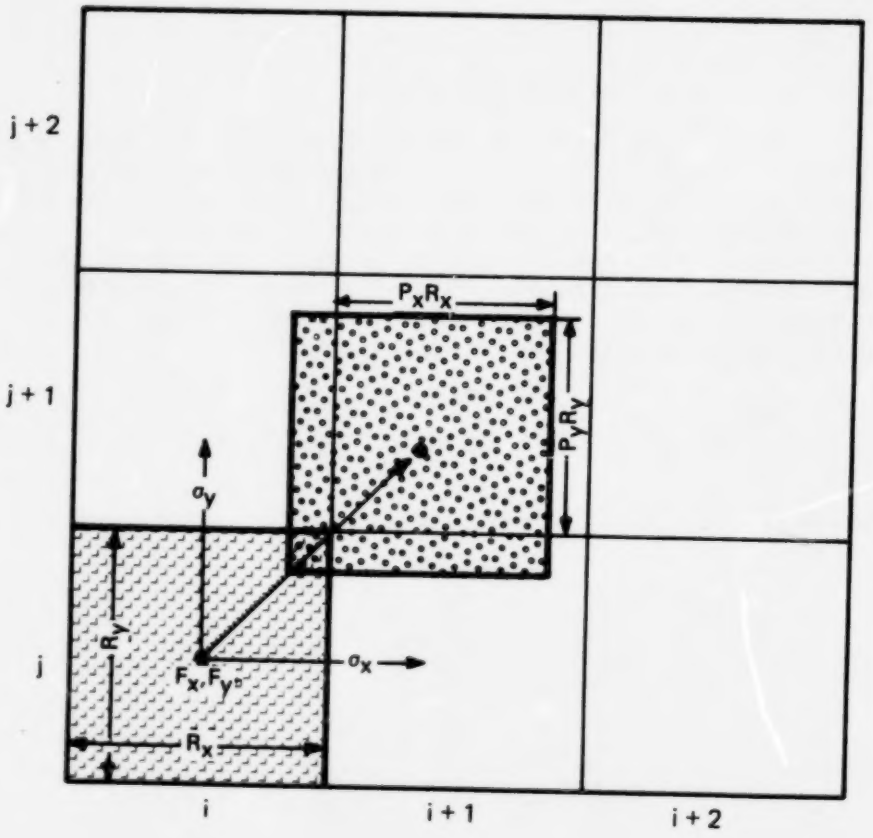


Figure 2-3 Scale Parameters for the Advection of a Rectangular Block of Uniformly Mixed Material

$$\left(R^{T+1}\right)^2 = \frac{\Sigma C_m R_m^2}{C^{T+1}} - 12\left(F^{T+1}\right)^2 + 12\,\frac{\Sigma F_m^2\, C_m}{C^{T+1}} \qquad (2\text{-}12)$$

### 2.4.2 Vertical Diffusion

The vertical diffusion terms $\partial/\partial z(K_z \partial C/\partial z)$ in Equations 2-1 and 2-2 are simulated by a conventional forward-time, centered-difference technique modified so that the vertical grid spacing can be variable. (The MESOGRID model is easily modified to include more vertical levels if computer resources and budgets permit.) In regions where parameters or concentrations change rapidly with height, resolution and accuracy can be improved with smaller vertical grid spacing. The vertical diffusion calculation may be represented by

$$C_k^{T+1} = (1 - \gamma_{k+1} - \gamma_{k-1})\, C_k^T + \gamma_{k+1}\, C_{k+1}^T + \gamma_{k-1}\, C_{k-1}^T,$$

where the horizontal subscript m is now suppressed, and

$$\gamma_{k+1} = \frac{(K_k + K_{k+1})\Delta t}{\Delta z_k\,(\Delta z_k + \Delta z_{k+1})}$$

$$\gamma_{k-1} = \frac{(K_k + K_{k-1})\Delta t}{\Delta z_k\,(\Delta z_k + \Delta z_{k-1})} \qquad (2\text{-}13)$$

The diffusivities $K_k$ are calculated at the center of each grid element, and $\Delta z_k$ denotes the depth of the kth grid element. The diffusive computational stability criterion requires that the $\gamma$'s are less than 0.5. The first and second moments of the horizontal distribution are maintained in the diffusive transfer by two additional equations:

$$F_k^{T+1} = \left[\left(1 - \gamma_{k+1} - \gamma_{k-1}\right) C_k^T F_k^T + \gamma_{k+1}\, C_{k+1}^T F_{k+1}^T + \gamma_{n-1}\, C_{n-1}^T F_{n-1}^T\right] / C_k^{T-1} \qquad (2\text{-}14)$$

$$\left(R^2\right)_k^{T+1} = \Bigg\{ C_k^T \left[ \left(R^2\right)_k^T + 12\left(F_k^T - F_k^{T+1}\right)^2 \right] \left(1 - \gamma_{k+1} - \gamma_{k-1}\right) + \gamma_{k+1}\, C_{k+1}^T \left[ \left(R^2\right)_{k+1}^T + 12\left(F_{k+1}^T - F_{k+1}^{T+1}\right)^2 \right] + \gamma_{k-1}\, C_{k-1}^T \left[ \left(R^2\right)_{k-1}^T + 12\left(F_{k-1}^T - F_{k-1}^{T+1}\right)^2 \right] \Bigg\} / C_k^{T+1} \qquad (2\text{-}15)$$

### 2.4.3 Calculation of Spatially Variable $K_z$ Profiles

MESOGRID computes spatially variable profiles of vertical eddy diffusivity for use in the vertical dispersion algorithms. The scheme uses the mixing depth, wind speed, and stability class information provided by MESOPAC to compute $K_z$ profiles in each of two altitude regimes: (1) the surface layer of depth S = 0.1H and (2) the Ekman layer extending from the top of the surface layer to the mixing height H.

To develop the profiles of $K_z$ in the boundary layer, it is assumed that atmospheric pollutants diffuse in the same manner as heat. The vertical eddy diffusivity in the surface boundary layer is then given by:

$$K_z = \frac{0.35\, u_* \, z}{\phi_h\left(\frac{z}{L}\right)} \qquad (2\text{-}16)$$

where

$u_*$ is the friction velocity,

$z$ is height above ground,

$L$ is the Monin-Obukhov length,

$\phi_h$ is the nondimensional potential temperature gradient.

By definition, $\phi_h\left(\frac{z}{L}\right)$ equals 1 for neutral conditions $\left(\frac{z}{L} = 0\right)$ in the surface layer. For stable conditions

$$\phi_h\left(\frac{z}{L}\right) = 1 + 4.7\,\frac{z}{L} \; ; \qquad (2\text{-}17a)$$

and for unstable conditions ($z/L > 0$)

$$\phi_h\left(\frac{z}{L}\right) = \left(1 - 15\,\frac{z}{L}\right)^{-1/2} . \qquad (2\text{-}17b)$$

Substitution of Equations (2-17a and 2-17b) into Equation (2-16) yields for stable conditions

$$K_z = \frac{0.35u_* z}{1 + 4.7\,\frac{z}{L}} ; \qquad (2\text{-}18a)$$

and for unstable conditions

$$K_z = 0.35u_* z\left(1 - 15\,\frac{z}{L}\right)^{1/2} . \qquad (2\text{-}18b)$$

The value of $u_*$ is taken to be 0.035 $u_f$, where $u_f$ is the "free stream" wind velocity (Blackadar 1962). If the MESOPAC model is used to compute wind fields, the winds may not be significantly less than the free stream wind speeds as long as the reference level chosen to describe the wind fields falls typically within the upper two-thirds of the boundary layer.

If the Monin-Obukhov length L is assigned a value dependent on the PGT stability class estimated by MESOPAC, the surface layer $K_z$ profiles become stability-dependent as well. Table 2-1 depicts values of $L^{-1}$ as a function of PGT stability class for a typical roughness length $z_o$ = 25 cm, as suggested by Golder (1972).

TABLE 2-1

INVERSE MONIN-OBUKHOV LENGTH $L^{-1}(m^{-1})$ AS A FUNCTION OF PGT STABILITY CLASS, FOR ROUGHNESS LENGTH $z_o$ = 25 cm (AFTER GOLDER 1972)

| | PGT Stability Class | | | | | |
|---|---|---|---|---|---|---|
| | A | B | C | D | E | F |
| $L^{-1}$ | -0.11 | -0.05 | -0.01 | - | 0.01 | 0.05 |

To develop the $K_z$ profiles in the Ekman layer, MESOGRID uses an interpolation method suggested by O'Brien (1970) to determine diffusivities between the top of the surface layer (S) and the top of the mixed layer (H). Taking into account the physical requirement that the first derivative of $K_z$ be continuous with height in the Ekman layer, O'Brien formulated the second-order equation

$$K_z = \frac{(z - H)^2}{(H - S)^2} \cdot \left\{ K_S + (z - S) \cdot \left[ \left. \frac{\partial K_z}{\partial z} \right|_S + 2 \frac{K_S}{H - S} \right] \right\} \qquad (2\text{-}19)$$

where

- $z$ is the height at which $K_z$ is to be determined
- $H$ is the height of the mixed layer (from MESOPAC)
- $S$ is the height of the surface layer
- $K_S$ is the value of $K_z$ at the top of the surface layer (from Equation 2-16)
- $\left. \frac{\partial K_z}{\partial z} \right|_S$ is the derivative of $K_z$ evaluated at S.

Here, it is assumed that $K_z$ approaches zero at the top of the mixed layer. Three stability-dependent equations for $\partial K_z/\partial z|_S$ are formulated by differentiating Equation 2-16 and evaluating at height S:

For unstable conditions

$$\left. \frac{\partial K_z}{\partial z} \right|_S = 0.35 u_* \left( 1 - 22.5 \frac{S}{L} \right) \left( 1 - 15 \frac{S}{L} \right)^{-1/2} ; \qquad (2\text{-}20a)$$

for neutral conditions

$$\left. \frac{\partial K_z}{\partial z} \right|_S = 0.35 u_* ; \qquad (2\text{-}20b)$$

and for stable conditions

$$\left.\frac{\partial K_z}{\partial z}\right|_S = 0.35 u_* \left(1 + 4.7 \frac{S}{L}\right)^2 . \qquad (2\text{-}20c)$$

Table 2-2 contains formulations for surface-layer $K_z$ (Equation 2-16) and $\partial K_z/\partial z|_S$ (Equation 2-20) appropriate to each PGT stability class, using the stability-dependent values of $L^{-1}$ from Table 2-1.

Equations 2-16 through 2-20 are used by MESOGRID to calculate values of $K_z$ at the mean height $z_k$ of each vertical grid element whenever the meteorological data is updated by MESOPAC. Because of the way the MESOGRID model characterizes vertical diffusion the mixing depth, H cannot be used directly as the depth through which pollutants diffuse in the vertical. However, the effect of a mixing lid can be simulated approximately--MESOGRID sets $K_z$ in a grid cell essentially to zero if the mean grid cell lies above the mixing height. Referring to the example in Figure 2-2, if the mixing depth H lies between 1,000 and 2,750 meters, $K_z$ is set to zero in the uppermost layer but is left unchanged in the two lower layers. But because diffusive transfer of mass by two contiguous vertical grid cells is made proportional to the average of the $K_z$ values for each cell (Equation 2-13), without further modification of the $K_z$ profiles, mass transfer would take place between Levels 2 and 3 even though Level 3 lies entirely above the mixing depth. MESOGRID will correct partially for this behavior; the average of $K_z$ for Levels 2 and 3 will be set equal to zero if $1{,}000 \leq H < 1{,}500$ m, but will be unchanged if $1{,}500 \leq H < 2{,}750$ m.

### 2.4.4 Numerical Stability Criteria

As described before, computational stability of the computational scheme is ensured only if:

$$\frac{u\Delta t}{\Delta d} \leq 1 \qquad (2\text{-}21)$$

and

$$\frac{(K_k + K_{k\pm1})\,\Delta t}{\Delta z_k (\Delta z_k + \Delta z_{k\pm1})} \leq 0.5 \qquad (2\text{-}22)$$

TABLE 2-2

STABILITY-DEPENDENT EXPRESSIONS FOR $K_z$ IN THE SURFACE LAYER AND $\left.\frac{\partial K_z}{\partial z}\right|_S$

| PGT Stability | $K_z$ (surface layer) | $\left.\frac{\partial K_z}{\partial z}\right\|_S$ |
|---|---|---|
| A | $0.35u_*z(1 + 1.65\ z)^{1/2}$ | $0.35u_*(1 + 2.48\ S)(1 + 1.65\ S)^{-1/2}$ |
| B | $0.35u_*z(1 + 0.75\ z)^{1/2}$ | $0.35u_*(1 + 1.13\ S)(1 + 0.75\ S)^{-1/2}$ |
| C | $0.35u_*z(1 + 0.15\ z)^{1/2}$ | $0.35u_*(1 + 0.23\ S)(1 + 0.15\ S)^{-1/2}$ |
| D | $0.35u_*z$ | $0.35u_*$ |
| E | $0.35u_*z(1 + 0.05\ z)^{-1}$ | $0.35u_*(1 + 0.05\ S)^2$ |
| F | $0.35u_*z(1 + 0.23\ z)^{-1}$ | $0.35u_*(1 + 0.23\ S)^2$ |

Equation (2-21), the advective stability criterion (Courant condition) means that a parcel of mass must not be advected, in either horizontal direction, through a distance greater than one grid space $\Delta d$ within a time step $\Delta t$. Equation (2-22) means that the effective vertical diffusion velocity $(K_k + K_{k\pm1})/(\Delta z_k + \Delta z_{k\pm1})$ cannot be such that a parcel is displaced vertically (by diffusion) more than a distance $\Delta z_k/2$ within $\Delta t$.

Given the maximum values of u and $K_z$ at the beginning of each hour, MESOGRID calculates the maximum time step allowed by the more stringent of these stability criteria, except that the actual time steps used by MESOGRID are constrained to be even fractions of one hour; thus the possible choices for $\Delta t$ are 5, 6, 7.5, 10, 15, 20, 30, and 60 minutes. Note that, notwithstanding the above, MESOGRID does not currently allow selection of a time step shorter than 5 minutes.

Table 2-3 lists the maximum values wind velocity u and $K_z$ values (expressed as averages between adjacent levels, e.g., $\overline{K}_{1.5} = (K_1 + K_2)/2$, for the nominal choices ($\Delta d$ = 40,000 m, $\Delta z_1$ = 500 m, $\Delta z_2$ = 1,000 m, and $\Delta z_3$ = 2,500 m). Under stable conditions, the advective criterion will normally dominate, whereas for unstable conditions (resulting in computed $K_z$ values up to $10^3$ in test simulations), the vertical diffusion stability criterion may dominate. Specific choices of horizontal and vertical grid cell dimensions can yield stability criteria significantly different from those of the hypothetical example. For instance, if the desired near-ground vertical resolution dictates choice of a small $\Delta z$ value, the maximum time step may be determined by the diffusion criteria, whatever the stability class.

In the MESOGRID model simulations performed by Bass et al. (1979), it was often found that for unstable conditions, $K_z$ would be so large that the time steps necessary to ensure computational stability were smaller than the minimum value deemed reasonable for regional-scale transport ($\Delta t$ = 5 minutes). Because such small time steps result in very expensive computing costs, a method, explained next, has been provided to give the user a degree of control over the diffusion-specified time step by systematically decreasing very large values of $K_z$. Such a procedure may be justifiable if the MESOGRID model is used for regional-scale simulations (as distinct from near-source impacts). Because, in a grid model, the magnitude of $K_z$ values determines the rapidity with which vertical mixing will occur by diffusion--as long as the reduced $K_z$ values lead to uniform vertical mixing within travel distances that are small compared to the regional transport scales of interest, the effect on regional-scale concentration patterns should be minimal (unless ground-level removal processes are of dominant importance).

The approach taken here forces the model to reduce large values of $K_z$ to within a range consistent with both the advective stability time step $\Delta t_a$ (Equation 2-21) and a user-specified "requested" time step $\Delta t_r$. There are six distinct cases delineated in Table 2-4 for modification or

TABLE 2-3

MAXIMUM VALUES OF u AND $\overline{K}_{1.5}$, $\overline{K}_{2.5}$ VS.
TIME STEP $\Delta t$ FOR NOMINAL MODEL PARAMETERS

| Model Time Step $\Delta t$ (min) | Advective Stability Criterion u(m $s^{-1}$) | Diffusive Stability Criterion $\overline{K}_{1.5}$($m^2$ $s^{-1}$) | $\overline{K}_{2.5}$($m^2$ $s^{-1}$) |
|---|---|---|---|
| 5 | 135 | 625 | 2916 |
| 15 | 45 | 208 | 972 |
| 30 | 22 | 104 | 486 |
| 60 | 11 | 52 | 293 |

Assumptions: $\Delta d$ = 40,000 m
$\Delta z_1$ = 500 m
$\Delta z_2$ = 1,000 m
$\Delta z_3$ = 2,500 m

TABLE 2-4

DETERMINING WHEN MESOGRID WILL MODIFY $K_z$ PROFILES

| Case Number | Possible Time Step Orderings | Modify $K_z$? |
|---|---|---|
| 1 | $\Delta t_a \leq \Delta t_d \leq \Delta t_r$ | No |
| 2 | $\Delta t_a \leq \Delta t_r \leq \Delta t_d$ | No |
| 3 | $\Delta t_r \leq \Delta t_a \leq \Delta t_d$ | No |
| 4 | $\Delta t_r \leq \Delta t_d \leq \Delta t_a$ | No |
| 5 | $\Delta t_d < \Delta t_r \leq \Delta t_a$ | Yes, in accordance with $\Delta t_r$ |
| 6 | $\Delta t_d < \Delta t_a < \Delta t_r$ | Yes, in accordance with $\Delta t_a$ |

nonmodification of $K_z$; these six cases are the six possible orderings of $\Delta t_r$, $\Delta t_a$ and the diffusive stability time step $\Delta t_d$ (Equation 2-22) by increasing magnitude. No modification of $K_z$ is required in Cases 1, 2, and 3, because the advective stability criterion is at least as stringent as the diffusive stability criterion, thus the model selects a time step shorter than that required by the largest $K_z$ values. In Case 4, the diffusive stability criteria is more stringent than the advective stability criteria, but no $K_z$ modification is necessary because $\Delta t_r \leq \Delta t_d$. For Cases 5 and 6, both $\Delta t_a$ and $\Delta t_r$ are greater than $\Delta t_d$, and modification of $K_z$ profiles is required. In Case 5, large $K_z$ values are reduced to within a range acceptable to $\Delta t_r$, whereas in Case 6, large values are reduced in accordance with $\Delta t_a$. In both cases, a $K_z$ profile that violates either of the diffusive stability criteria in Table 2-3 is uniformly reduced by an appropriate scaling factor--the shape of the profile is maintained.

The "requested" time step procedure gives the user a measure of control over the time steps selected by the model and, thus, the cost of a model simulation. The procedure results in the modification of the fewest number of $K_z$ profiles by the smallest amount necessary to enable use of either $\Delta t_r$ or $\Delta t_a$.

## 2.5 Boundary Conditions

The MESOGRID model permits horizontal boundary concentrations of $SO_2$ and $SO_4^=$ to be specified independently for each vertical level and at each east-west and north-south boundary face of the computational region. The boundary value concentrations are assumed to occupy fictitious grid cells adjacent to the boundary of the regular grid. These concentrations are then advected into the grid using the procedure described in Section 2.4.1. These boundary values, which have default values of zero, are assumed to be time independent.

The boundary condition describing mass transfer through the "top" of the computational region is specified in terms of a reflection coefficient. The reflection coefficient is user-specified and can range from complete reflection of mass from the upper boundary (value of unity) to total loss of material through the upper boundary (value of zero). The boundary condition describing mass transfer out of the bottom of the grid is user-specified through the 'deposition velocity' concept. Section 2.7 gives a more detailed description of the bottom boundary condition.

## 2.6 Conversion of Sulfur Dioxide to Sulfate

MESOGRID represents the conversion of $SO_2$ to $SO_4^=$ as a simple linear rate function. The changes in mass of each pollutant in one time step $\Delta t$ are given by:

$$\Delta Q^n(SO_2) = k_1 Q^n(SO_2) \Delta t \quad (2\text{-}23a)$$

$$\Delta Q^n(SO_4^=) = -1.5 k_1 Q^n(SO_2) \Delta t \quad (2\text{-}23b)$$

where $Q^n(SO_2)$ is the mass of $SO_2$ at the beginning of the nth time step, and $k_1$ ($s^{-1}$) is the conversion rate constant. MESOGRID uses the nominal value $k_1 = -5.56 \times 10^{-6}$, as suggested by Hales et al. (1977), unless otherwise specified by the user.

It should be noted that the conversion of $SO_2$ to $SO_4^=$ represented by Equation 2-23 is (1) made independent of the vertical or horizontal distribution of $SO_2$ within a plume, and (2) independent of whether a plume lies above or below the mixing height.

When Equation 2-23 is applied to an individual grid cell after the advection calculation and prior to the diffusion calculation, the changes in concentrations of $SO_2$ and $SO_4^=$ resulting from linear conversion are:

$$\Delta C^n(SO_2) = k_1 C^n(SO_2) \Delta t \quad (2\text{-}24a)$$

$$\Delta C^n(SO_4^=) = -1.5 k_1 C^n(SO_2) \Delta t \quad (2\text{-}24b)$$

where, for example, $C^n(SO_2)$ is the grid cell concentration of $SO_2$ at time step n, following the horizontal advection operation.

## 2.7 Dry Deposition of Sulfur Dioxide and Sulfate

The changes of mass $\Delta Q^n(g)$ of each pollutant at time step n resulting from dry deposition are given by:

$$\Delta Q^n(SO_2) = -\left[v_d(SO_2) Q_1^n(SO_2) \Delta t\right]/\Delta z_1 \quad (2\text{-}25a)$$

$$\Delta Q^n(SO_4^=) = -\left[v_d(SO_4^=) Q_1^n(SO_4^=) \Delta t\right]/\Delta z_1 \quad (2\text{-}25b)$$

where $Q^n(SO_2)$ and $Q^n(SO_4^=)$ are the total masses of $SO_2$ and $SO_4^=$, respectively, in a vertical column at the beginning of time step n ($Q_1^n$ is the mass in the lowest cell); $v_d(SO_2)$ and $v_d(SO_4^=)$ are the deposition velocities of $SO_2$ and $SO_4^=$ respectively; and $\Delta z_1$ is the vertical depth of the lowest grid layer. MESOGRID uses $v_d(SO_2) = 0.01$ (m $s^{-1}$) and $v_d(SO_4^=) = 0.001$ (m $s^{-1}$), the nominal values of Hales et al. (1977), unless otherwise specified by the user.

There is an important difference in the way mass is depleted by MESOGRID as compared to the plume and puff models; although the amounts of $SO_2$ and $SO_4^=$ removed by dry deposition are the same in each model for vertically uniform distributions, MESOGRID depletes mass in only the lowest of its vertical layers rather than throughout the entire mixing depth (as do the other models). However, since MESOGRID exercises the dry deposition algorithm before the vertical diffusion algorithm, mass loss in a cell in the lowest grid layer is redistributed through cells in the upper layers (as long as they are below the mixing lid). Therefore, if the effective "diffusion velocity" (see Section 2.4.4) is large, the dry deposition algorithm in MESOGRID yields equivalent results as the algorithm in the other models.

## 2.8 Plume Rise

The effective emission height $h_e$ of each point source is computed as $h_e = h_s + h_p$, where $h_s$ is the stack height (m) and $h_p$ is the plume rise (m). The plume rise equations used by the MESOGRID model are those described by Briggs (1975) for equilibrium (final) plume rise.
For unstable and neutral conditions with $h' \leq H$ (i.e., the plume does not rise into an elevated stable layer)

$$h_p = h' = 1.6\, F^{1/3}\, (3.5\, x^*)^{2/3}\, u^{-1}; \qquad (2\text{-}26a)$$

For unstable and neutral conditions with $h' > H$ (i.e., the plume penetrates into an elevated stable layer)

$$h_p = \text{MIN}\{h', (z_b^3 + 18.75\, F\, u_m^{-1}\, S^{-1})^{1/3}\} \qquad (2\text{-}26b)$$

for stable conditions when $u \geq 1.37$ m s$^{-1}$

$$h_p = 2.6\, F^{1/3}\, S^{-1/3} u^{-1/3}; \qquad (2\text{-}26c)$$

for stable conditions when $u < 1.37$ m s$^{-1}$

$$h_p = 5.0\, F^{1/4}\, S^{-3/8}; \qquad (2\text{-}26d)$$

where:

$F$ = buoyancy flux ($m^4\ s^{-3}$)

$x^* = 34.49\, F^{0.4}$ for $F > 55$

$= 14.0\, F^{0.625}$ for $F \leq 55$

$S = (g/T)(\partial\theta/\partial z)$

$g = 9.8\ m\ s^{-2}$

$T = 290°K$

$\partial\theta/\partial z = 0.0137°K\ m^{-1}$

$H$ = mixing depth (m)

$z_b = H - h_s$ (m)

$u$ = wind speed ($m\ s^{-1}$)

$u_m$ = MAX {u, 1.37}

## 2.9 THE MESOGRID Computer Program

MESOGRID is a highly modular computer program which shares with MESOPUFF and MESOPLUME standardized input/output features and, where possible, identical program modules. The computer program flow chart (Figure 2-4) outlines the order of execution of the individual modules described at length in the 'MESOGRID Technical Discussion'.

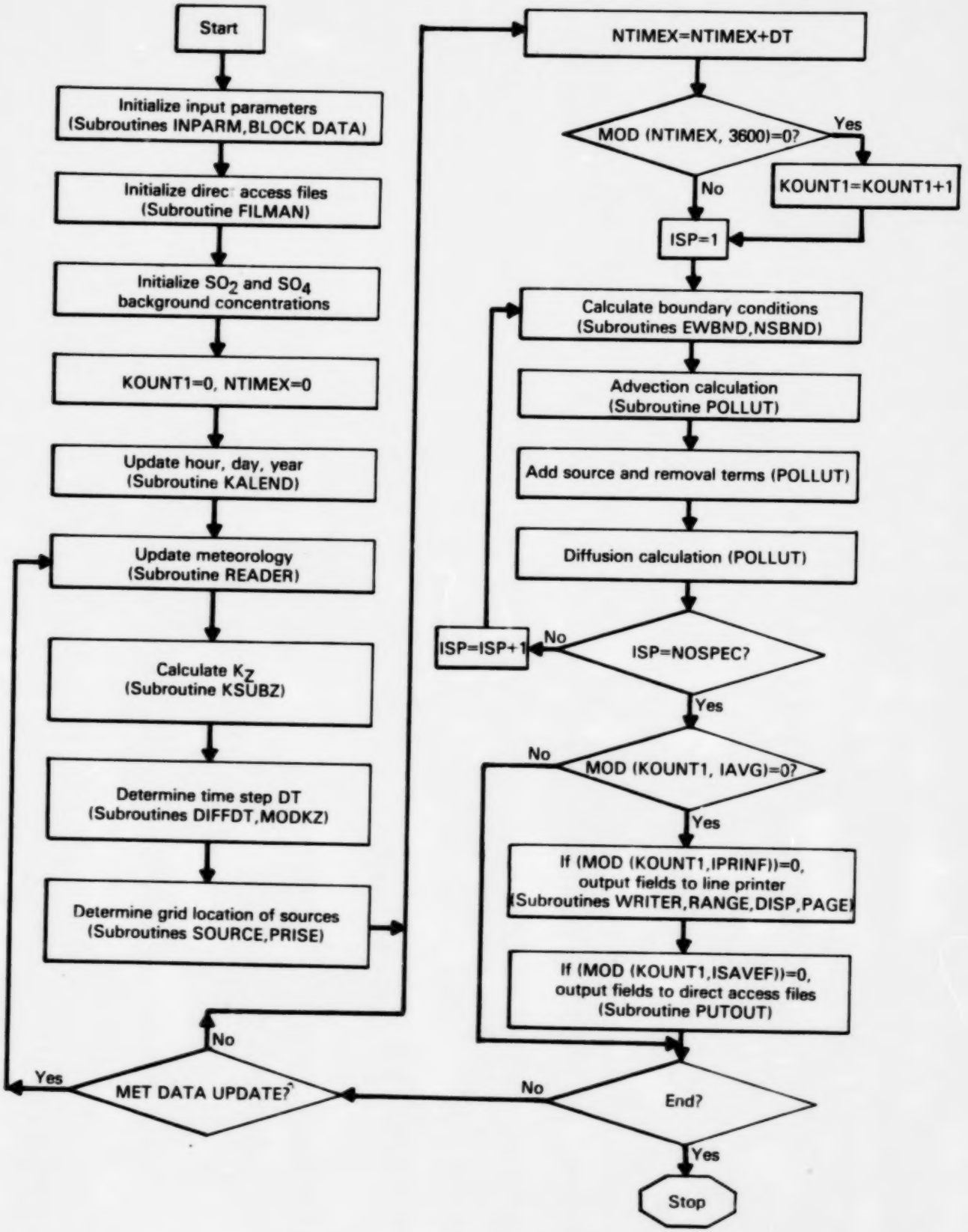


Figure 2-4 MESOGRID Flow Chart

# 3. MESOGRID USER INSTRUCTIONS

## 3.1 General

A MESOGRID model simulation requires the following two input data sets:

- meteorological fields from MESOPAC (unformatted disk or tape input via logical unit 2) and
- model simulation control parameters and emission source inventory (cards or card-image disk input via logical unit 5)

A complete description of model simulation control parameter and emission source inventory input is contained in Section 3.2. For most convenient operation, MESOGRID should interface with the output of the MESOPAC meteorological preprocessor (see Section 3.3).

Concentration array output of a MESOGRID simulation can be routed to either (or both) of the following:

- line printer (logical unit 6) and
- direct-access disk storage system (logical units 13, 15, 21, 22, 23, and 24).

Both optional output media are discussed in detail in Section 3.4. The direct access storage system allows for automatic storage, cataloguing, and easy retrieval of all output data files from MESOGRID and its sister regional-scale models MESOPUFF and MESOPLUME. Availability of on-line direct-access disk storage enables the user to invoke the powerful MESOFILE file-management system, designed especially for interface with the regional-scale models. The MESOFILE system has file management components that produce, for each run for which output has been requested for disposal to disk, a record of the date of the run, the run characteristics, the disk file locations of all the concentration data output, and the values of all the input parameters for the run. The MESOFILE program allows this information to be retrieved for all the previous runs made on a particular set of disk files. The MESOGRID program contains a file management subroutine (FILMAN) which determines without further user input the proper locations for all of the various MESOGRID disk output files. MESOFILE can then be used for flexible time averaging of any set of fields, summation of different model simulations, statistical comparison of model results, and graphical contour display.

## 3.2 Description of Card-Image Input

This section provides a detailed description of all the card-image input requirements of the MESOGRID model, model simulation control parameters, and emission inventory. The input package has been designed

for use in common by all three mesoscale models (MESOPLUME, MESOPUFF, and MESOGRID) especially to facilitate intermodel comparison tests. The common input subroutine (INPARM) reads in all model simulation control parameters in Fortran NAMELIST format so that input parameters common to all three models can be included in standardized NAMELIST blocks. A few model-specific NAMELIST sets, however, are required because of certain features peculiar to each model algorithm. There are thirteen NAMELIST blocks included within the INPARM subroutine package, as follows: (1) MODEL, (2) CONTR, (3) GRID, (4) SIGMA, (5) METD, (6) PUFF1, (7) PUFF2, (8) PLUM1, (9) PLUM2, (10) GRIDY, (11) REMOV, (12) OUTPT, and (13) SOURC. NAMELIST blocks SIGMA, PUFF1, PUFF2, PLUM1, and PLUM2 are not used by MESOGRID and must be omitted from the input data runstream.

The remainder of this section provides detailed descriptions of the parameters in each NAMELIST set.* These NAMELIST sets are to be included in the input run stream in the identical sequence described above.

NAMELIST TITLE--MODEL

MODEL defines which model is to be run. Initialize LGRID = .TRUE. for a MESOGRID run.

| Parameter | Type | Definition | Default |
|---|---|---|---|
| LPLUME | LOGICAL | If .TRUE., MESOPLUME is to be run | .FALSE. |
| LPUFF | LOGICAL | If .TRUE., MESOPUFF is to be run | .FALSE. |
| LGRID | LOGICAL | If .TRUE., MESOGRID is to be run | .FALSE. |

NAMELIST TITLE--CONTR

CONTR initializes computational control variables.

| Parameter | Type | Definition | Default |
|---|---|---|---|
| DTIME | REAL | Length of the basic or 'requested' time step (hours) | 1.0 |
| NADVTS | INTEGER | Length of the simulation (hours) | 24 |

*The description of certain parameters that were retained from an earlier version of the model but not otherwise used or that were included only to perform various model sensitivity tests, are omitted from this discussion--these parameters would not be activated by the average user. However, for a complete list of possible input parameters, the interested reader should consult the documentation included as comment cards directly in subroutine INPARM.

| Parameter | Type | Definition | Default |
|---|---|---|---|
| MTFREQ | INTEGER | Interval between wind, mixing depth, and stability fields updates (hours)--must be equal to or an even multiple of the MESOPAC time step 'ISTEP' (hours) | 1 |
| IAVG | INTEGER | Number of hours over which output concentration arrays are to be averaged | 24 |

NAMELIST TITLE--GRID

GRID initializes parameters defining the two major grids: meteorological and basic computational. The basic computational grid must be a subset of the meteorological grid and also must have the same grid spacing. Currently, the maximum allowable size of the basic computational is 26 by 26 horizontal grid indices.

| Parameter | Type | Definition | Default |
|---|---|---|---|
| IELMET | INTEGER | Number of elements in the x-direction of the meteorological grid--must be the same as 'IMAX' used by MESOPAC (must be $\leq$ 40). | 26 |
| JELMET | INTEGER | Number of elements in the y-direction of the meteorological grid--must be the same as 'JMAX' used by MESOPAC (must be $\leq$ 40). | 26 |
| DELTMT | REAL | Basic computational grid spacing (meters)--must be equal to the grid spacing, DX, used by the MESOPAC meteorological grid. | 40,000. |
| IASTAR | INTEGER | Element number of the meteorological grid where the basic computational grid starts (x-direction). | 1 |
| IASTOP | INTEGER | Element number of the meteorological grid where the basic computational grid stops (x-direction). | 26 |
| JASTAR | INTEGER | Element number of the meteorological grid where the basic computational grid starts (y-direction). | 1 |
| JASTOP | INTEGER | Element number of the meteorological grid where the basic computational grid stops (y-direction). | 26 |

NAMELIST TITLE--METD

METD initializes parameters that identify the input meteorological data base.

| Parameter | Type | Definition | Default |
|---|---|---|---|
| METSRT | INTEGER | Year (2 digits), Julian day (3 digits), and hour (2 digits) in the MESOPAC output data file at which the MESOPLUME run begins. | 7700101 |
| METCOD | INTEGER | 4-digit serial number to identify the meteorological data used (previously assigned by the user to the MESOPAC simulation run that generated the input meteorology fields). | 1001 |

NAMELIST TITLE--GRIDY

For MESOGRID only, GRIDY initializes computational parameters.

| Parameter | Type | Definition | Default |
|---|---|---|---|
| INVL | INTEGER | Number of vertical layers in the 3-dimensional grid (must be either 2 or 3). | 3 |
| CZ(4) | REAL | Height of the grid lines (m). 'CZ(1)'=0; 'CZ(2)' = height of the top of the lowest layer; 'CZ(3)' = height of the top of the second layer; 'CZ(4)'= height of the top of the third layer (if necessary). | 0.,500., 1500.,4000. |
| NOSPEC | INTEGER | Number of species modeled (1 = $SO_2$ only is modeled, 2 = $SO_2$ and $SO_4^=$ are modeled). | 2 |
| CREFLT | REAL | Reflection coefficient at the top of the highest layer. (1.0 = complete reflection, 0.0 = complete absorption). | 1 |

| Parameter | Type | Definition | Default |
|---|---|---|---|
| LBACK | LOGICAL | If .TRUE., background values for $SO_2$ and $SO_4^=$ are to be read in. | .FALSE. |
| CBOUND (A,B,C) | REAL | This is the boundary value concentration array ($\mu g\ m^{-3}$) (A is incremented the fastest, C is incremented the slowest). A=1,2 for $SO_2$ and $SO_4^=$, respectively; B=1,2,3,4 for the west, north, east, and south grid boundaries, respectively; C = 1,2,3 for the 1st, 2nd, and 3rd grid level, respectively. | 24*0. |
| BACK2 | REAL | Background value for $SO_2$ ($\mu g\ m^{-3}$)--at every grid cell--This is applied only at the very first time step of the run. For a continuous background, set, 'CBOUND' elements equal to 'BACK2' and 'BACK4' values. | 0. |
| BACK4 | REAL | Background value for $SO_4^=$ ($\mu g\ m^{-3}$) at every grid cell. | 0. |
| NPTS | INTEGER | If 'LPRINT' = .TRUE. (see Namelist OUTPT), the rate (hours) for output of a variety of grid and source information (2 pages per basic time step). | 9999. |
| NPKZ | INTEGER | If 'LPRINT' = .TRUE., the rate of $K_Z$ array output (2-6 pages depending on number of levels and size of grid). | 9999. |

NAMELIST TITLE--REMOV

REMOV assigns values to the removal rate parameters.

| Parameter | Type | Definition | Default |
|---|---|---|---|
| LDCAY | LOGICAL | If .TRUE., exponential decay of $SO_2$ to $SO_4^=$ is simulated; If .FALSE., no decay is simulated. | .TRUE. |

| Parameter | Type | Definition | Default |
|---|---|---|---|
| EXTNCT | REAL | If 'LDCAY' is .TRUE., conversion rate of $SO_2$ to $SO_4^=$ (negative, for loss of $SO_2$). | $-5.56 \times 10^{-6}$ |
| LDEPOT | LOGICAL | If .TRUE. dry deposition is simulated for both species. If .FALSE., dry deposition is not simulated for either specie. | .TRUE. |
| DEPVEL(2) | REAL ARRAY | If 'LDEPOT' is .TRUE., 'DEPVEL(1)' and, 'DEPVEL(2)' are deposition velocities (m $s^{-1}$) for $SO_2$ and $SO_4^=$, respectively. | (.01,.001) |

NAMELIST TITLE--OUTPT

OUTPT initializes the output control parameters.

| Parameter | Type | Definition | Default |
|---|---|---|---|
| LPRINT | LOGICAL | Is .TRUE. if line printer output of gridded concentration arrays is desired. | .TRUE. |
| IPRINF | INTEGER | If 'LPRINT' is .TRUE., specifies the rate (hours) of gridded concentration array output (to line printer) Must be equal to or an even multiple of 'IAVG' (see NAMELIST CONTR). | 24 |
| LSAVE | LOGICAL | If .TRUE., concentration arrays are to be saved on disk or tape. | .FALSE. |
| ISAVEF | INTEGER | If 'LSAVE' is .TRUE., the rate (hours) of concentration array output to tape or disk. Must be an even multiple of 'IAVG' (see NAMELIST CONTR). | 24 |

NAMELIST TITLE--SOURC

SOURC assigns values to the parameters associated with source characteristics.

| Parameter | Type | Definition | Default |
|---|---|---|---|
| NSOURC | INTEGER | Number of sources (up to 50). | 1 |

The following formatted (non-NAMELISTED) input follows the NAMELISTED input described above: For each source (there are a total of 'NSOURC' sources) one formatted card of stack parameters must be included.

STACK PARAMETERS (1 card per source)

| Columns | Format | Parameter | Definition |
|---|---|---|---|
| 1-10 | F10.2 | STAKHT | Stack height (m) above ground |
| 11-20 | F10.2 | XXSTAK | x-coordinate of source (meteorological grid units) |
| 21-30 | F10.2 | YYSTAK | y-coordinate of source (meteorological grid units) |
| 31-40 | F10.2 | EMISS(1) | Emission rate ($g\ s^{-1}$) for $SO_2$ |
| 41-50 | F10.2 | EMISS(2) | Emission rate ($g\ s^{-1}$) for $SO_4^=$ |
| 51-60 | F10.2 | BFLUX | Buoyancy flux ($m^4\ s^{-3}$) for plume rise |

## 3.3 Other Input Considerations

### 3.3.1 Meteorological Considerations and MESOPAC Input

The meteorological input for the MESOGRID model is specified as a time sequence of spatially variable, gridded fields of horizontal (u,v) wind components, mixing depth, and PGT stability class. These fields are generated and written to off-line storage (disk or tape) by the MESOPAC* Meteorological Preprocessing Program (see Benkley and Bass 1979c). As mentioned in Section 3.1, MESOGRID retrieves the meteorological data set from logical unit 2.

Direct compatibility of MESOGRID input with MESOPAC output is ensured if the successive runs of MESOPAC and MESOGRID jointly satisfy the following constraints on respective run parameters.

- The four-digit serial number 'METCOD' used to identify the meteorological data sets requested by MESOGRID must match the 'METCOD' assigned when MESOPAC created and tagged its output meteorological data set.

- The grid spacing 'DELTMT' used by MESOGRID must be identical to the grid spacing 'DX' used by MESOPAC; of course, the number of horizontal grid elements 'IELMET' and 'JELMET' used to specify the met data array sizes in both models must be identical.

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*If desired, another meteorological preprocessing routine, if properly designed, can be substituted to drive the MESOGRID model.

- the geographical area covered by the MESOGRID basic computational grid must be identical to, or a subset of the area covered by the MESOPAC meteorological grid.

- the chronological time period over which the MESOGRID simulation run is performed must be a subset of the time period used by MESOPAC to define the meteorological fields.

- the interval at which the meteorological fields are updated by MESOGRID 'MTFREQ' (hours) must be equal to or an even multiple of the time interval 'ISTEP' (hours) used by MESOPAC to generate and output successive sets of meteorological fields.

### 3.3.2 Array Size Considerations

Currently, MESOGRID allows for the basic computational grid to be as large as 26 elements in each horizontal direction and 3 elements in the vertical direction. Since most of the large arrays in MESOGRID are related to the grid size, the size of the grid cannot be increased without directly increasing the core required by MESOGRID. The user can specify up to 50 sources; it would be trivial to increase the number of sources, however, and this increase would not significantly increase model storage needs.

## 3.4 MESOGRID Model Output

MESOGRID output can be specified in either (or both) of two media depending on further user needs. The results can be output directly to the line printer, and/or routed for storage on the direct-access disk storage system for subsequent postprocessing. This section describes the types of output data that can be routed through each system. In most cases, the user may specify whether a certain type of output data will be received.

### 3.4.1 Line Printer Output

The following is a complete list of the line printer output options available from a MESOGRID simulation:

- a table that lists the values of all input parameters used in the run (this output is always generated);

- arrays of ground-level concentrations for $SO_2$ (always output) and $SO_4$ (output if 'NOSPEC' = 2) block averaged over time intervals of 'IAVG' hours and output at intervals of 'IPRINF' hours during the run (these fields are printed only if 'LPRINT' = .TRUE.);

- a table of information, output every 'NPTS' hours, describing allowable advection and diffusion time steps, number of gridded values of $K_z$ that were adjusted based on the 'requested' time step, and aggregate grid cell source data (this information is provided only if 'LPRINT' = .TRUE.); and

- an array of $K_z$ values for each level, output every 'NPKZ' hours (these arrays are output only if 'LPRINT' = .TRUE.).

### 3.4.2 Direct Access Disk Output

Table 3-1 describes the logical unit file structure of the direct access disk storage system expected by MESOGRID. (Model outputs are only directed to direct access disk storage when 'LSAVE' = .TRUE.) As indicated, six distinct direct access files are used, each with independent size characteristics; these file characteristics are currently frozen within the MESOGRID code itself via Fortran "Define File" statements and may require specific modification for adaptation to the user's host system.

Concentration Files 21 and 22 contain the $SO_2$ and $SO_4^=$ concentration fields for each output time step. An identifying header record identical to the format used for File 15 (see File 15 description below) precedes the concentration fields. Files 21 and 22 can accommodate a maximum of 1,800 records each; therefore, for example, the results of 10 independent model simulations, each of 179 hours duration with hourly output, will fit exactly within the 1,800 records allotted. Note that if only $SO_2$ is modeled ('NOSPEC' = 1), $SO_4^=$ arrays output to File 22 will contain all zeroes.

The library file (13) contains a single-record descriptor for each model run; File 13 can accommodate a maximum of 25 independent model runs. A hard copy printout of the library file produced by MESOFILE is shown in Figure 4-2 in the next section.

The parameters defining each model simulation run are as follows:

INUMB - a model run number which is automatically assigned by the direct access disk output subroutine.

DATFLD - The date of execution (day, month, and year) of the model run [not the day (or days) simulated].

MODEL - The particular mesoscale dispersion model chosen from the integrated modeling mesoscale system--in this case, MESOGRID.

TABLE 3-1

LOGICAL UNIT FILE STRUCTURE

| Device Logical Unit Number | File Name | Record Structure |
|---|---|---|
| 13 | Library | 25 records, 14 words/record |
| 15 | NAMELIST | 25 records, 800 words/record |
| 21 | $SO_2$ Concentration | 1,800 records, 1,610 words/record |
| 22 | $SO_4^=$ Concentration | 1,800 records, 1,610 words/record |
| 23 | Run Number | 1 record, 2 words |
| 24 | Pointer | 1 record, 4 words |

YR/DAY/HR - The year, Julian day, and hour on which the model simulation begins (Note that the first gridded concentration field is not output until 'ISAVEF' hours subsequently.

NGRIDS - The total number of concentration arrays output for each pollutant during the model simulation ('NGRIDS' = 'NADVTS'/'ISAVEF' where 'NADVTS' is the total number of time steps in the model simulation.)

IAVG - The concentration array averaging rate (hours).

ISAVEF - The concentration array direct-access disk output rate (hours).

ISAFE - The direct access address of the duplicate File 15 record.

IBEGIN - The direct access address of the first of the 'NGRIDS' number of arrays output to File 21 for $SO_2$ and File 22 for $SO_4^=$.

ISTOP - The direct access address of the last of the 'NGRIDS' number of arrays to File 21 for $SO_2$ and File 22 for $SO_4^=$.

ICHECK - The run termination status indicator 'ICHECK' = 1 indicates the model simulation terminated normally; 'ICHECK' = 0 indicates it terminated abnormally. In the latter case, the results of this run must be deleted from the file management system using the program BACKUPØ1 (see Scire et al. 1979) before another run is made.

NAMELIST File 15 contains a one-record detailed description of the parameters used for each model run. Each record in File 15 contains: (1) a duplicate of the corresponding FILE 13 record for the run and (2) the NAMELIST parameters used to make the run (also output to the line printer).

Finally, the Run Number and Pointer Files (23 and 24) preserve information between runs necessary to maintain proper archival sequencing of run outputs--they are invisible to the user.

## 3.5 Execution Time and Core Requirements

The run time required for a MESOGRID simulation is determined by the number of time steps, the number of grid points, and various meteorological factors that control the time step $\Delta t$ satisfying the horizontal and vertical computational stability criteria (see Section 2.4.4).

Note especially that MESOGRID execution time varies directly with the number of grid points but is independent of the number of sources. MESOGRID becomes cost-effective compared to the plume and puff models only when large numbers of sources are to be included. The execution time (on an IBM 370/158) of MESOGRID for the computational grid and typical meteorological conditons used is described by:

$$t(\text{sec}) = \frac{300\ N^*}{\Delta t} \qquad (3\text{-}1)$$

where $N^*$ is the total number of time steps (of duration $\Delta t$ minutes) in a MESOGRID simulation. Table 2-3 (see Section 2) listed the maximum values of u and $K_z$ consistent with various choices of $\Delta t$, assuming a horizontal grid interval of 40 km and vertical layer thicknesses of 500, 1,000 and 2,500m. On the IBM 370/158 system, MESOGRID requires 380k bytes of core storage.

# 4. TEST CASE FOR MESOGRID

A test case is provided in this section to familiarize the user with the operation of the MESOGRID model and to verify that the model is running properly on his system. The test case included here is a 3-day sequence of MESOGRID model output for the time period 0000 Greenwich Mean Time (GMT) June 14, 1978 through 0000 GMT June 17, 1978 in the Four Corners area of the southwestern United States [the first three days of the five-day run sequence studied in detail by Bass et al. (1979)]. A 10-source partial emission inventory was selected from the full set of energy-related major point sources of $SO_2$ in the Four Corners area. To save on computational costs, $SO_4^=$ is not modeled in the test case.

Figure 4-1 contains the run control parameters and emission source inventory (input on logical unit 5) for this test case. Note that most of the model input variables assume their default values. Appendix A contains the entire input data set used by the MESOPAC preprocessor to generate the meteorological fields that were subsequently read in by MESOGRID (on logical unit 2). Appendix A also contains a very small portion of the MESOPAC model output--included to aid the user in verifying the full test case.

The full set of line printer output for this MESOGRID test case is included in Appendix B. Descriptions of the model output fields assigned to the direct access disk storage system (as echoed in hard copy form by the MESOFILE system) are shown in Figure 4-2 (the library file) and in Appendix C (the NAMELIST file). In this example, the results from the MESOGRID test case are stored together with the results from the MESOPUFF and MESOPLUME test cases as discussed in the MESOPLUME user's manual (Benkley and Bass 1979a) and the MESOPUFF user's manual (Benkley and Bass 1979b). Appendix C also shows the NAMELIST file; there, the library record NAMELIST input parameters and emission source data are stored for future reference.

The MESOFILE postprocessing system (Scire et al. 1979) operates on the direct access disk output files produced by MESOGRID, to produce various forms of result analyses. Figure 4-3 illustrates one such option--a Calcomp contour plot of the 24-hour average ground-level $SO_2$ concentration field for June 16, 1978 as obtained from the test case. (Concentration isopleth values are not printed directly on the contour plot, but the user can generate an equivalent line printer plot, as illustrated in Figure 4-4, which does include the actual isopleth values.) Figure 4-5 illustrates the bulk statistical descriptors (described by Bass et al. 1979) used to compare, for example, two time sequences of model result fields. In this example, the base case 24-hour average ground-level $SO_2$ concentration fields for June 16 computed by the MESOPLUME model are compared to those computed by the MESOGRID model.

```
&MODEL LGRID=.TRUE. &END
&CONTR NADVTS=72 &END
&GRID &END
&METD METSRT=7816500,METCOD=1003 &END
&GRIDY NOSPEC=1 &END
&REMOV &END
&OUTPT LSAVE=.TRUE. &END
&SOURC NSOURC=10 &END
236.      8.8       8.8       2560.     0.        6397.
152.      23.4      14.0      343.8     0.        1503.
152.      17.2      18.9      633.4     0.        2847.
152.      23.7      13.0      488.      0.        3353.
183.      13.5      1.2       53.7      0.        3016.
229.      10.0      13.1      320.      0.        6222.
76.2      8.0       19.5      146.9     0.        240.
183.      9.7       15.2      1310.8    0.        3016.
175.      0.9       8.0       268.8     0.        1047.
152.      1.5       4.1       1011.     0.        11144.
```

Figure 4-1 MESOGRID Test Case Parameter and Emission Source Inventory Input

| INUMB | DATFLD | MODEL | YR/DAY/HR | NGRIDS | IAVG | ISAVEF | ISAFE | IBEGIN | ISTOP | ICHECK |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 12 FEB 1979 | MESOPLUM | 78/165/ 0 | 3 | 24 | 24 | 1 | 2 | 4 | 1 |
| 2 | 12 FEB 1979 | MESOPUFF | 78/165/ 0 | 5 | 24 | 24 | 5 | 6 | 8 | 1 |
| 3 | 12 FEB 1979 | MESOGRID | 78/165/ 0 | 3 | 24 | 24 | 9 | 10 | 12 | 1 |

Figure 4-2 Test Case Library File (MESOFILE)



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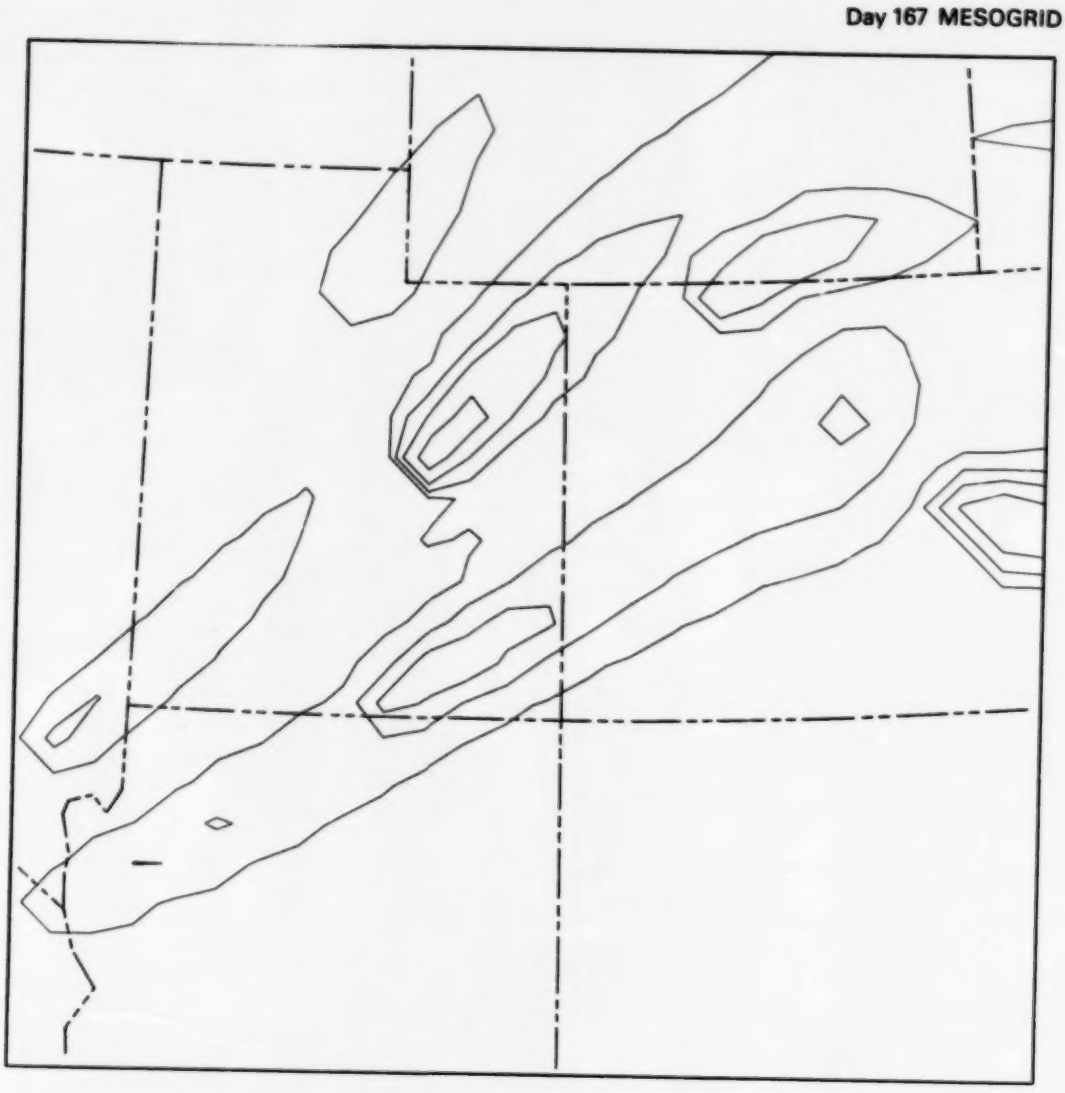


Figure 4-3 MESOGRID 24-Hour Average $SO_2$ Concentration Calcomp Plot, 16 June, 1978 (from MESOFILE)

PLOT NUMBER: 9
VALUE THRESHOLD (MICROGRAMS)
0 -0.00 LE X LT 0.10
1 0.10 LE X LT 0.50
2 0.50 LE X LT 1.00
3 1.00 LE X LT 2.00
4 2.00 LE X LT 5.00
5 5.00 LE X LT 10.00
6 10.00 LE X LT 25.00
7 25.00 LE X LT 50.00
8 50.00 LE X

Figure 4-4 MESOGRID 24-Hour Average $SO_2$ Concentration Line Printer Plot, 16 June, 1978 (from MESOFILE)

```
THE FOLLOWING RECORDS WERE USED AS THE BASE FIELD:
FIRST RECORD =     34      LAST RECORD =     34

THE FOLLOWING RECORDS WERE USED AS THE PERTURBED FIELD:
FIRST RECORD =     28      LAST RECORD =     28


STATISTICS FOR THE SET OF ALL GRID POINTS:


AVERAGE BASE FIELD VALUE (AVEB) =  0.19558E-06
AVERAGE PERTURBED FIELD VALUE (AVEP) =  0.15684E-06
AVERAGE DEVIATION (AD) =  0.38742E-07
AVERAGE ABSOLUTE DEVIATION (AAD) =  0.19383E-06
MAXIMUM LOCAL DEVIATION (XMLD) =  0.80800E-05
DIFFERENCE OF MAXIMA (DLM) B-P = -0.38003E-05
FRACTIONAL DIFFERENCE OF MAXIMA (FDLM) B-P = -0.88800E+00
MAXIMUM BASE FIELD VALUE (XMBF) =  0.42797E-05
MAXIMUM PERTURBED FIELD VALUE (XMPF) =  0.80800E-05


STATISTICS FOR THE SET OF POINTS WITHIN THE UNION OF THE TWO PLUMES:

AVERAGE DEVIATION (AD1) =  0.65310E-07
AVERAGE ABSOLUTE DEVIATION (AAD1) =  0.32675E-06
CORRELATION COEFFICIENT (RBA) =  0.27


STATISTICS FOR THE SET OF POINTS WITHIN THE INTERSECTION OF THE TWO PLUMES:

AVERAGE DEVIATION (AD0) =  0.13115E-06
AVERAGE ABSOLUTE DEVIATION (AAD0) =  0.37787E-06
AVERAGE FRACTIONAL DEVIATION (AFD0) = -0.35815E+02
AVERAGE ABSOLUTE FRACTIONAL DEVIATION (AAFD0) =  0.36738E+02
MAXIMUM ABSOLUTE FRACTIONAL DEVIATION (XMLFD0) =  0.88961E+04


PLUME CHARACTERISTICS


TOTAL NUMBER OF GRID POINTS =      676
NUMBER OF GRID POINTS CONTAINED IN THE INTERSECTION OF THE BASE AND PERTURBED PLUMES =      287
NUMBER OF NON-ZERO CONCENTRATIONS (BASE OR PERTURBED) =      401
NUMBER OF GRID POINTS IN THE BASE PLUME =      338
NUMBER OF GRID POINTS IN THE PERTURBED PLUME =      350
AVERAGE BASE PLUME VALUE (AVEB0) =  0.39116E-06
AVERAGE PERTURBED PLUME VALUE (AVEP0) =  0.30292E-06
FRACTIONAL DEVIATION OF THE MEANS (FDM) =  0.22558E+00
```

Figure 4-5 Bulk Statistical Comparison of MESOPLUME to MESOGRID, 16 June, 1978 (from MESOFILE)



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# REFERENCES

Bass A., C. W. Benkley, J. S. Scire, and C. S. Morris. 1979. Development of Mesoscale Air Quality Simulation Models Volume 1. Comparative Sensitivity Studies of Puff, Plume, and Grid Models for Long-Distance Dispersion Modeling. EPA 600/7-79-XXX, Environmental Protection Agency, Research Triangle Park, NC, 210 pp.

Benkley, C. W. and A. Bass. 1979a. Development of Mesoscale Air Quality Simulation Models Volume 2. User's Guide to MESOPLUME (Mesoscale Plume Segment) Model. EPA 600/7-79-XXX, Environmental Protection Agency, Research Triangle Park, NC, 141 pp.

Benkley, C. W. and A. Bass. 1979b. Development of Mesoscale Air Quality Simulation Models Volume 3. User's Guide to MESOPUFF (Mesoscale Puff) Model. EPA 600/7-79-XXX, Environmental Protection Agency, Research Triangle Park, NC, 118 pp.

Benkley, C. W. and A. Bass. 1979c. Development of Mesoscale Air Quality Simulation Models Volume 6. User's Guide to MESOPAC (Mesoscale Meteorology Package). EPA 600/7-79-XXX, Environmental Protection Agency, Research Triangle Park, NC, 85 pp.

Blackadar, A. K. 1962. The Vertical Distribution of Wind and Turbulent Exchange in the Neutral Atmosphere. J. Geophys. Res. 67: 3095-3102.

Boris, J. P., and D. L. Book. 1973. Flux-corrected Transport--I. SHASTA, A Fluid Transport Algorithm That Works. Jour. Comp. Phys. 11:38-69.

Briggs, G. S. 1975. Plume Rise Predictions. Lectures on Air Pollution and Environmental Impact Analyses. American Meteorological Society, Boston, MA, p. 59-111.

Egan, B. A. and J. R. Mahoney. 1972. Numerical Modeling of Advection and Diffusion of Urban Area Source Pollutants. J. Appl. Meteor. 11:312-322.

Egan, B. A., K. S. Rao, and A. Bass. 1976. A Three-Dimensional Advective-Diffusive Model for Long Range Sulfate Transport and Transformation. Seventh International Technical Meeting on Air Pollution Modeling and its Application, Airlie, VA, September 7-10, 1976, p. 697-714.

Golder, P. 1972. Relations Among Stability Parameters in the Surface Layer. Bound. Layer Meteor. 3:47-58.

Hales, J. M., D. C. Powell and T. D. Fox. 1977. STRAM-An Air Pollution Model Incorporating Non-linear Chemistry, Variable Trajectories, and Plume Segment Diffusion. EPA 450/3-77-012. Environmental Protection Agency, Research Triangle Park, NC, 147 pp.

REFERENCES (Continued)

O'Brien, J. J., 1970. A Note on the Vertical Structure of the Eddy Exchange Coefficient in the Planetary Boundary Layer. J. Atmos. Sci. 27:1213-1215.

Scire, J. S., J. E. Beebe, C. W. Benkley and A. Bass. 1979. Development of Mesoscale Air Quality Simulation Models Volume 5. User's Guide to the MESOFILE Postprocessing Package. EPA 600/7-79-XXX, Environmental Protection Agency, Research Triangle Park, NC, 67 pp.

Start, G. E. and L. L. Wendell. 1974. Regional Effluent Dispersion Calculations Considering Spatial and Temporal Meteorological Calculations. NOAA Tech. Memo. ERL-ARL-44, National Oceanic and Atmospheric Administration, Washington, DC, 63 pp.

# APPENDIX A

# TEST CASE MESOPAC INPUT AND OUTPUT

```
MESOPAC TEST CASE -- DAYS 165 THROUGH 167, 1978
   26    26    18     1     1                                          1003
0016578    0016878
40000.     0.0001                    1.0                        50
.TRUE.      .TRUE.      .TRUE.
.TRUE.      .TRUE.        12     0
 INW 10.0  3.7
 UCC -0.7  8.3
 ABQ 19.1  3.7
 GJT 14.5 14.7
 TUS  9.6 -4.0
 DEN 22.9 16.9
 LND 15.1 25.9
 SLC  7.8 19.8
 ELY  1.5 15.7
 BOI -0.4 27.7
 WMC -4.2 20.8
 RAP 26.0 28.8
 LBF 31.4 21.3
 DDC 34.8 12.3
 AMA 30.8  5.0
 MAF 29.2 -4.3
 ELP 19.6 -5.2
 SAN -5.2 -2.8
 016578       18
 BOI              26.0                    6.5  3.0
 RAP              32.2                    5.8  5.8
 WMC              27.8                    3.9  6.7
 LND              30.2                    6.3  5.3
 SLC              32.8                    5.0 10.7
 LBF              28.2                    5.0 -1.3
 ELY              28.2                    2.8  4.9
 GJT              33.2                    5.1  3.5
 DEN              29.4                    0.2  2.0
 DDC              29.4                    5.3  1.9
 UCC             999.0                  999.0999.0
 INW              34.4                    6.7  4.7
 ABQ              28.2                    5.6  1.0
 AMA              27.8                    8.0  4.6
 SAN              30.0                    9.9  8.3
 TUS              39.4                    3.6  0.3
 ELP              35.0                    2.3  1.1
 MAF              31.6                    0.4  4.6
1216578       18
 BOI        914. 10.6 12.8  3.2-14.1  6.9  8.3
 RAP        903. 18.8 21.8 10.4-11.9 14.7-10.3
 WMC        869.  8.2 13.4  3.8-12.3 12.6  8.9
 LND        830. 11.6999.0 11.0-11.5  7.1  4.1
 SLC        896. 21.6 23.6 11.4 -9.5  9.9  8.3
 LBF        916. 18.2 26.2 13.0-10.9  7.5  6.3
 ELY        809. 10.2999.0 10.0 -9.5  7.2 12.5
 GJT        853. 18.2 19.4 12.4 -7.7  7.5  3.5
 DEN        839. 13.2999.0 12.8 -8.3  9.4 -2.5
 DDC        927. 18.2 22.0 10.0-10.3  4.6  8.0
 UCC       9999.999.0999.0999.0999.0999.0999.0
```

```
 INN       855. 16.0 17.4 11.6 -7.1  5.9  5.0
 ABQ       842. 18.8999.0 13.8-11.1  6.5 -3.0
 AMA       895. 18.2 19.8 11.0 -8.1  7.1 -1.3
 SAN      1000. 17.0 15.8 11.2 -7.3 14.0  6.5
 TUS       924. 23.0 27.2 14.2 -6.5  5.5  5.5
 ELP       884. 21.2 22.2 13.2 -9.7999.0999.0
 MAF       918. 18.8 21.4 12.4 -8.5  2.6 -0.2
 016678     18
 BOI          23.8                  10.4  2.8
 RAP          29.4                   4.8 10.3
 RMC          25.0                   8.3  6.9
 LND         999.0                 999.0999.0
 SLC          30.6                   2.4 13.7
 LBF          33.2                   3.3  5.8
 ELY          28.0                   4.6  9.8
 GJT          31.0                   3.3  5.8
 DEN          32.2                  -2.9  2.9
 DDC          33.8                   6.6 -1.2
 UCC         999.0                 999.0999.0
 INW          35.0                   7.3  7.3
 ABQ          35.0                   3.2  2.6
 AMA          31.0                   7.6  4.4
 SAN          23.8                  19.3  7.0
 TUS          40.0                   8.6  1.5
 ELP          36.6                  -1.1  2.9
 MAF         999.0                 999.0999.0
1216678     18
 BOI       917.  8.2  9.0  3.5-19.1  8.2 -0.7
 RAP      9999.999.0999.0999.0999.0999.0999.0
 RMC       870.  6.6  7.6  2.3-17.1  5.1  0.9
 LND       825. 10.6999.0 11.4-10.1  8.7  3.2
 SLC       868. 15.6 17.4  8.2-12.1  4.6 12.6
 LBF       911. 17.8 23.2 15.6 -9.9  1.9  7.0
 ELY       807.  8.4999.0  8.4-12.3  3.5  5.1
 GJT       851. 20.6 22.4 10.8 -9.9  7.6  5.3
 DEN       836. 18.8999.0 13.2 -9.1  9.9  2.7
 DDC       921. 21.6 25.8 14.2 -7.1 14.7  7.5
 UCC      9999.999.0999.0999.0999.0999.0999.0
 INW       853. 20.0 19.8 13.0 -8.3 12.6 10.6
 ABQ       840. 17.2999.0 13.4 -5.9999.0999.0
 AMA       891. 20.0 22.8 14.6 -7.3  6.1  0.5
 SAN      1002. 16.0 17.6 11.6 -7.7 13.4  7.7
 TUS       924. 23.2 24.4 13.6 -7.5  9.8  5.7
 ELP       882. 24.8 27.0 15.4 -5.9  6.7  0.6
 MAF       917. 20.6 22.0 13.8 -7.1 -2.5  0.7
 016778     18
 BOI          19.4                  11.4  3.1
 RAP          29.4                  10.6  3.9
 RMC          22.8                   5.0  7.2
 LND          27.2                   7.3  7.3
 SLC          26.6                   4.7  6.7
 LBF         999.0                   9.2  0.8
 ELY          23.8                   8.6 10.2
 GJT          33.2                   6.5  6.5
 DEN          34.0                   9.7 -0.9
```

```
DDC          36.0                    12.9  7.5
UCC         999.0                  999.0999.0
INW          33.2                    10.3  4.8
ABQ          35.6                    10.6  1.9
AMA          35.0                     9.7  6.8
SAN          22.0                    15.2  2.7
TUS         999.0                  999.0999.0
ELP         999.0                  999.0999.0
MAF          33.2                     2.3 -4.0
1216778      18
BOI        918.  6.6 10.8  3.5-20.5  7.6 -5.3
RAP        904. 13.8 13.4  6.8-11.9  5.5 -1.5
HMC        870.  6.6  8.0 -0.9-23.5  1.4  3.9
LND      9999.999.0999.0999.0999.0999.0999.0
SLC        870. 13.8 13.8  5.4-12.7  2.6  7.3
LBF        910. 18.8 21.8 15.0 -9.1  4.7 -4.0
ELY      9999.999.0999.0999.0999.0999.0999.0
GJT      9999.999.0999.0999.0999.0999.0999.0
DEN      9999.999.0999.0999.0999.0999.0999.0
DDC        920. 23.2 26.6 15.6 -6.9 11.6  4.2
UCC      9999.999.0999.0999.0999.0999.0999.0
INW      9999.999.0999.0999.0999.0999.0999.0
ABQ      9999.999.0999.0999.0999.0999.0999.0
AMA        890. 21.6 27.4 16.2 -7.7  8.5  4.9
SAN      9999.999.0999.0999.0999.0999.0999.0
TUS      9999.999.0999.0999.0999.0999.0999.0
ELP      9999.999.0999.0999.0999.0999.0999.0
MAF        916. 21.0 25.2 14.6 -6.3 -1.5 -0.3
016878       18
BOI          20.6                     9.1 -1.6
RAP          22.2                     4.3  5.1
HMC          21.6                     3.4 -0.3
LND         999.0                  999.0999.0
SLC          25.6                    10.8  0.9
LBF          28.8                     6.2  3.6
ELY          21.6                     8.0  5.6
GJT          31.6                    12.5  7.2
DEN          31.6                     0.2 -1.0
DDC          36.6                    10.5 10.5
UCC         999.0                  999.0999.0
INW          32.8                     9.8  5.7
ABQ          34.4                    11.8 -0.0
AMA          34.4                     5.5  3.8
SAN          23.4                    10.4  1.6
TUS          38.4                     3.8 -2.7
ELP          38.0                     4.5 -1.2
MAF          34.4                     2.9 -2.1
```

A-3

********** MESOPAC **********

STATION DATA FOR 0 166 78 (HOUR,DAY,YEAR)

| STATION | U | V | DEPTH | STAB |
|---|---|---|---|---|
| INW | 7.3 | 7.3 | 4130. | 3 |
| UCC | 999.0 | 999.0 | 9999. | 9 |
| ABQ | 3.2 | 2.6 | 4265. | 1 |
| GJT | 3.3 | 5.8 | 2656. | 2 |
| TUS | 8.6 | 1.5 | 3534. | 2 |
| DEN | -2.9 | 2.9 | 3861. | 1 |
| LND | 7.1 | 4.1 | 9999. | 9 |
| SLC | 2.4 | 13.7 | 1578. | 3 |
| ELY | 4.6 | 9.8 | 3743. | 3 |
| BOI | 18.4 | 2.8 | 1982. | 3 |
| WMC | 8.3 | 6.9 | 2815. | 3 |
| RAP | 4.8 | 10.3 | 1442. | 3 |
| LBF | 3.3 | 5.8 | 1019. | 2 |
| DDC | 6.6 | -1.2 | 2612. | 2 |
| AMA | 7.6 | 4.4 | 2029. | 2 |
| MAF | 2.6 | -0.2 | 9999. | 9 |
| ELP | -1.1 | 2.9 | 5264. | 1 |
| SAN | 19.3 | 7.0 | 1088. | 4 |

ONLY NON-MISSING DATA IS USED TO CONSTRUCT ALL FIELDS AT EACH TIME STEP

********** MESOPAC **********

U-FIELD FOR 0 166 78 (HOUR,DAY,YEAR) 2 ITERATIONS SCAN RADIUS= 9.0 GRID SPACES FIELD IN UNITS OF 10** -1

| | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 78 | 85 | 82 | 78 | 71 | 65 | 59 | 56 | 53 | 55 | 53 | 58 | 61 | 66 | 68 | 70 | 68 | 65 | 62 | 55 | 49 | 44 |
| 64 | 71 | 69 | 70 | 64 | 59 | 54 | 51 | 49 | 51 | 50 | 52 | 56 | 60 | 63 | 64 | 62 | 59 | 55 | 51 | 46 | 42 |
| 51 | 62 | 64 | 63 | 57 | 52 | 47 | 43 | 42 | 40 | 43 | 44 | 50 | 54 | 57 | 55 | 55 | 52 | 47 | 41 | 39 | 34 |
| 48 | 57 | 59 | 58 | 53 | 45 | 42 | 38 | 37 | 35 | 37 | 39 | 42 | 46 | 45 | 45 | 44 | 41 | 39 | 35 | 29 | 26 |
| 47 | 55 | 56 | 54 | 48 | 41 | 37 | 33 | 31 | 32 | 32 | 33 | 36 | 40 | 38 | 37 | 35 | 30 | 28 | 25 | 19 | 14 |
| 45 | 53 | 53 | 52 | 47 | 40 | 35 | 31 | 29 | 28 | 29 | 31 | 33 | 34 | 31 | 31 | 26 | 23 | 18 | 14 | 8 | 5 |
| 43 | 51 | 51 | 50 | 46 | 41 | 34 | 32 | 29 | 28 | 28 | 29 | 30 | 28 | 27 | 26 | 21 | 17 | 11 | 3 | 1 | 6 |
| 40 | 48 | 48 | 49 | 45 | 42 | 36 | 32 | 29 | 29 | 29 | 29 | 29 | 26 | 27 | 24 | 19 | 15 | 7 | 1 | 6 | 13 |
| 38 | 45 | 45 | 47 | 45 | 42 | 39 | 34 | 31 | 29 | 29 | 29 | 29 | 28 | 28 | 24 | 20 | 14 | 7 | 1 | 9 | 16 |
| 39 | 44 | 45 | 46 | 45 | 43 | 40 | 36 | 33 | 29 | 27 | 28 | 28 | 29 | 29 | 27 | 22 | 15 | 4 | 4 | 12 | 17 |
| 39 | 44 | 44 | 46 | 46 | 43 | 40 | 37 | 33 | 31 | 29 | 28 | 29 | 29 | 31 | 29 | 25 | 17 | 8 | 1 | 10 | 14 |
| 40 | 43 | 44 | 46 | 45 | 44 | 41 | 37 | 34 | 31 | 31 | 29 | 30 | 31 | 32 | 31 | 25 | 19 | 11 | 3 | 6 | 10 |
| 42 | 44 | 44 | 46 | 45 | 43 | 43 | 40 | 39 | 36 | 35 | 35 | 34 | 34 | 32 | 31 | 26 | 20 | 14 | 8 | 1 | 3 |
| 42 | 48 | 45 | 46 | 46 | 45 | 44 | 42 | 41 | 40 | 38 | 38 | 36 | 36 | 33 | 29 | 26 | 21 | 16 | 10 | 7 | 3 |
| 40 | 48 | 47 | 47 | 45 | 44 | 47 | 45 | 44 | 43 | 43 | 43 | 40 | 37 | 35 | 31 | 28 | 24 | 18 | 15 | 11 | 11 |
| 44 | 49 | 52 | 54 | 53 | 51 | 50 | 49 | 48 | 46 | 47 | 43 | 43 | 41 | 39 | 38 | 32 | 28 | 25 | 20 | 18 | 17 |
| 48 | 49 | 51 | 56 | 59 | 59 | 57 | 57 | 56 | 56 | 54 | 48 | 49 | 48 | 45 | 42 | 39 | 31 | 29 | 23 | 24 | 22 |
| 49 | 59 | 55 | 58 | 59 | 60 | 61 | 61 | 61 | 60 | 57 | 56 | 55 | 53 | 49 | 46 | 42 | 39 | 32 | 32 | 28 | 32 |
| 50 | 54 | 61 | 63 | 62 | 64 | 66 | 66 | 65 | 63 | 61 | 61 | 59 | 56 | 52 | 48 | 44 | 41 | 38 | 36 | 35 | 35 |
| 87 | 69 | 68 | 69 | 69 | 65 | 67 | 67 | 68 | 67 | 67 | 66 | 65 | 60 | 53 | 48 | 45 | 41 | 38 | 36 | 37 | 39 |

A-5

********** MESOPAC **********

| | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 119 | 117 | 86 | 89 | 78 | 74 | 69 | 68 | 69 | 69 | 69 | 69 | 68 | 64 | 57 | 49 | 44 | 39 | 36 | 34 | 34 | 36 |
| 120 | 122 | 119 | 94 | 87 | 74 | 73 | 70 | 71 | 71 | 71 | 70 | 69 | 65 | 58 | 49 | 43 | 37 | 36 | 34 | 34 | 35 |
| 121 | 130 | 129 | 110 | 89 | 85 | 76 | 73 | 72 | 71 | 71 | 69 | 67 | 63 | 52 | 47 | 42 | 38 | 35 | 35 | 34 | 36 |
| 127 | 136 | 115 | 112 | 93 | 88 | 80 | 76 | 74 | 72 | 71 | 68 | 65 | 57 | 51 | 46 | 41 | 38 | 34 | 34 | 34 | 34 |
| 157 | 138 | 123 | 115 | 109 | 90 | 86 | 81 | 77 | 75 | 71 | 67 | 60 | 55 | 50 | 45 | 40 | 36 | 34 | 31 | 29 | 27 |
| 168 | 140 | 127 | 113 | 107 | 87 | 84 | 80 | 80 | 78 | 74 | 67 | 62 | 57 | 51 | 45 | 39 | 34 | 30 | 27 | 21 | 20 |

| | | | |
|---|---|---|---|
| 40 | 39 | 38 | 37 |
| 37 | 36 | 31 | 27 |
| 38 | 29 | 23 | 20 |
| 21 | 20 | 15 | 11 |
| 12 | 10 | 6 | 3 |
| 0 | 1 | 7 | 7 |
| 11 | 12 | 15 | 15 |
| 18 | 18 | 20 | 19 |
| 20 | 20 | 21 | 19 |
| 20 | 19 | 20 | 18 |
| 18 | 17 | 15 | 13 |
| 14 | 13 | 14 | 10 |
| 7 | 6 | 8 | 0 |
| 1 | 3 | 9 | 14 |
| 8 | 18 | 18 | 23 |
| 20 | 25 | 22 | 31 |
| 26 | 28 | 27 | 34 |
| 30 | 33 | 33 | 37 |
| 32 | 36 | 36 | 42 |
| 40 | 47 | 49 | 52 |

| | | | |
|---|---|---|---|
| 40 | 46 | 47 | 49 |
| 36 | 41 | 39 | 44 |
| 35 | 37 | 36 | 39 |
| 32 | 36 | 35 | 37 |
| 28 | 31 | 31 | 31 |
| 23 | 26 | 28 | 31 |

********** MESOPAC **********

V-FIELD FOR 0 166 78 (HOUR,DAY,YEAR) 2 ITERATIONS SCAN RADIUS= 9,8 GRID SPACES FIELD IN UNITS OF 10** -1

| | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 59 | 70 | 86 | 97 | 105 | 111 | 115 | 116 | 113 | 108 | 101 | 84 | 70 | 62 | 58 | 57 | 60 | 62 | 63 | 67 | 69 | 71 |
| 60 | 69 | 77 | 87 | 96 | 101 | 107 | 110 | 109 | 104 | 99 | 84 | 71 | 60 | 55 | 53 | 53 | 55 | 53 | 56 | 59 | 61 |
| 67 | 73 | 77 | 84 | 94 | 102 | 109 | 112 | 113 | 110 | 102 | 90 | 77 | 67 | 60 | 53 | 52 | 53 | 52 | 52 | 55 | 56 |
| 71 | 74 | 78 | 85 | 95 | 103 | 110 | 116 | 115 | 112 | 108 | 95 | 82 | 72 | 60 | 54 | 54 | 52 | 45 | 47 | 49 | 50 |
| 77 | 78 | 82 | 88 | 97 | 108 | 117 | 121 | 122 | 119 | 111 | 100 | 87 | 76 | 65 | 58 | 55 | 54 | 52 | 44 | 46 | 46 |
| 81 | 83 | 87 | 92 | 101 | 111 | 119 | 125 | 127 | 123 | 115 | 103 | 91 | 78 | 65 | 61 | 56 | 56 | 50 | 44 | 42 | 44 |
| 86 | 87 | 90 | 95 | 102 | 112 | 122 | 126 | 128 | 124 | 115 | 103 | 91 | 75 | 66 | 62 | 58 | 56 | 52 | 42 | 41 | 39 |
| 90 | 91 | 92 | 96 | 104 | 111 | 119 | 126 | 127 | 122 | 113 | 101 | 87 | 73 | 65 | 62 | 60 | 57 | 47 | 42 | 39 | 36 |
| 94 | 94 | 96 | 98 | 104 | 109 | 117 | 122 | 123 | 119 | 108 | 96 | 81 | 69 | 64 | 61 | 60 | 57 | 49 | 41 | 37 | 32 |
| 96 | 96 | 97 | 99 | 104 | 107 | 113 | 117 | 116 | 112 | 103 | 91 | 77 | 65 | 62 | 60 | 59 | 56 | 46 | 40 | 34 | 31 |
| 97 | 98 | 99 | 100 | 103 | 104 | 108 | 110 | 109 | 104 | 96 | 86 | 73 | 64 | 61 | 59 | 58 | 52 | 44 | 40 | 35 | 32 |
| 98 | 98 | 99 | 100 | 103 | 102 | 103 | 105 | 104 | 99 | 91 | 82 | 71 | 64 | 61 | 58 | 56 | 51 | 44 | 37 | 33 | 32 |
| 96 | 99 | 99 | 99 | 102 | 100 | 98 | 98 | 96 | 93 | 86 | 78 | 69 | 64 | 60 | 57 | 54 | 49 | 43 | 37 | 33 | 31 |
| 93 | 93 | 97 | 99 | 97 | 96 | 95 | 94 | 91 | 87 | 82 | 76 | 67 | 62 | 59 | 56 | 54 | 50 | 46 | 40 | 36 | 34 |
| 96 | 93 | 91 | 97 | 97 | 93 | 90 | 88 | 85 | 82 | 79 | 72 | 65 | 62 | 56 | 55 | 53 | 48 | 45 | 39 | 35 | 32 |
| 97 | 91 | 90 | 89 | 89 | 93 | 89 | 84 | 83 | 80 | 79 | 71 | 61 | 60 | 57 | 53 | 52 | 47 | 43 | 38 | 34 | 31 |
| 97 | 94 | 89 | 87 | 87 | 84 | 81 | 81 | 78 | 78 | 73 | 67 | 64 | 61 | 56 | 53 | 47 | 46 | 39 | 35 | 32 | 31 |
| 92 | 93 | 89 | 85 | 84 | 83 | 80 | 79 | 77 | 75 | 70 | 66 | 63 | 60 | 56 | 52 | 45 | 40 | 36 | 33 | 31 | 32 |
| 106 | 97 | 88 | 85 | 79 | 76 | 75 | 74 | 73 | 73 | 69 | 67 | 65 | 61 | 56 | 51 | 45 | 38 | 33 | 30 | 28 | 30 |
| 88 | 100 | 96 | 85 | 80 | 75 | 73 | 73 | 72 | 71 | 69 | 67 | 64 | 61 | 56 | 49 | 42 | 36 | 32 | 29 | 28 | 27 |

MESOPAC

| | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 72 | 78 | 92 | 87 | 76 | 68 | 66 | 69 | 70 | 69 | 69 | 68 | 64 | 59 | 54 | 48 | 41 | 34 | 30 | 28 | 28 | 29 |
| 76 | 75 | 73 | 85 | 70 | 66 | 65 | 65 | 67 | 68 | 68 | 67 | 63 | 59 | 51 | 42 | 37 | 33 | 30 | 29 | 29 | 29 |
| 71 | 75 | 68 | 63 | 68 | 59 | 61 | 61 | 64 | 66 | 67 | 65 | 62 | 56 | 46 | 40 | 35 | 32 | 30 | 29 | 29 | 28 |
| 84 | 68 | 57 | 54 | 52 | 58 | 54 | 57 | 57 | 60 | 60 | 59 | 55 | 48 | 41 | 35 | 31 | 28 | 27 | 27 | 26 | 24 |
| 72 | 54 | 47 | 43 | 48 | 50 | 50 | 53 | 54 | 56 | 57 | 54 | 48 | 43 | 37 | 32 | 28 | 26 | 25 | 26 | 24 | 22 |
| 37 | 30 | 29 | 30 | 30 | 34 | 44 | 46 | 49 | 49 | 46 | 43 | 38 | 32 | 26 | 22 | 19 | 18 | 18 | 17 | 15 | 19 |

********** MESOPAC **********

| | | | |
|---|---|---|---|
| 71 | 73 | 72 | 80 |
| 63 | 66 | 68 | 73 |
| 59 | 61 | 63 | 67 |
| 51 | 53 | 54 | 57 |
| 46 | 48 | 48 | 49 |
| 43 | 42 | 42 | 43 |
| 38 | 37 | 37 | 40 |
| 34 | 33 | 34 | 34 |
| 31 | 31 | 32 | 32 |
| 30 | 30 | 31 | 29 |
| 30 | 30 | 30 | 27 |
| 30 | 32 | 31 | 25 |
| 31 | 30 | 31 | 26 |
| 30 | 29 | 32 | 28 |
| 30 | 35 | 34 | 26 |
| 33 | 35 | 32 | 29 |
| 34 | 32 | 33 | 33 |
| 34 | 30 | 32 | 33 |
| 29 | 29 | 31 | 33 |
| 28 | 29 | 31 | 35 |

| | | | |
|---|---|---|---|
| 28 | 31 | 31 | 30 |
| 30 | 30 | 29 | 29 |
| 28 | 28 | 30 | 29 |
| 24 | 25 | 25 | 25 |
| 24 | 24 | 26 | 23 |
| 22 | 21 | 25 | 20 |

```
********************************************************** MESOPAC ***********************************************************
                                  MIXING DEPTH FIELD FOR  0 166 78 (HOUR,DAY,YEAR)    FIELD  IN UNITS OF  10**  0
 2192  2197  2215  2223  2209  2172  1734  1703  1683  1671  1578  1578  1578  1578  1989  2037  1578  2621  2571  2506  2422  2320
    +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +

 2349  2325  2310  2281  2229  2153  1988  1928  1648  1642  1578  1816  1875  1939  2001  2057  2644  2463  2720  2708  2654  2581
    +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +

 2501  2457  2401  2341  2242  2119  1924  1845  1806  1692  1734  1795  1870  1949  2023  2526  2664  2798  2842  2852  2850  2868
    +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +

 2633  2584  2515  2409  2257  2075  1905  1749  1754  1774  1704  1780  1874  1971  2394  2543  2687  2831  3339  2997  3037  3062
    +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +

 2754  2719  2642  2502  2294  2045  1818  1679  1641  1688  1791  1776  1894  2014  2417  2567  2712  2861  3019  3441  3204  3272
    +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +

 2892  2887  2815  2650  2388  2069  1807  1616  1578  1646  1773  1797  1944  2086  2457  2597  2733  2883  3053  3452  3577  3452
    +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +

 3073  3109  3054  2875  2570  2191  1849  1660  1617  1684  1823  1999  2036  2367  2511  2627  2744  2889  3071  3456  3610  3720
    +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +

 3295  3373  3340  3161  2882  2456  2054  1834  1769  1820  1949  2120  2170  2459  2570  2651  2740  2873  3232  3445  3633  3761
    +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +

 3542  3632  3618  3464  3150  2726  2335  2094  2000  2020  2122  2268  2320  2547  2618  2661  2721  2838  3164  3411  3630  3776
    +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +

 3632  3743  3743  3593  3324  2947  2593  2350  2234  2222  2289  2399  2442  2608  2646  2661  2696  2795  3089  3352  3591  3751
    +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +

 3633  3710  3706  3598  3381  3070  2770  2546  2421  2384  2416  2489  2510  2634  2656  2656  2681  2826  3028  3282  3519  3685
    +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +

 3574  3628  3618  3529  3398  3109  2867  2674  2551  2498  2659  2541  2530  2609  2655  2659  2683  2818  2996  3318  3435  3596
    +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +

 3643  3524  3509  3481  3348  3100  3059  2940  2855  2801  2766  2740  2651  2659  2697  2713  2818  2953  3132  3320  3483  3604
    +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +

 3610  3634  3465  3398  3400  3222  3125  3043  2978  2927  2883  2839  2720  2813  2857  2946  3020  3062  3213  3364  3495  3594
    +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +

 3743  3743  3743  3451  3408  3254  3197  3148  3106  3067  3023  2873  2996  2969  3076  3152  3212  3306  3332  3451  3551  3626
    +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +

 3743  3743  3836  3852  3874  3430  3285  3268  3252  3230  3195  3225  3400  3342  3309  3313  3417  3488  3568  3578  3649  3699
    +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +

 3743  3743  3870  3890  3915  3944  3709  3708  3698  3676  3617  3662  3608  3562  3537  3543  3582  3670  3731  3735  3780  3804
    +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +

 3743  3888  3905  3928  3954  3984  4013  3801  3815  3826  3861  3830  3788  3748  3727  3737  3777  3836  3890  3928  3925  3695
    +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +

 3743  3918  3938  3962  3989  4018  4045  4069  3941  3957  3981  3960  3924  3887  3869  3883  3928  3989  4044  4076  4079  3837
    +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +

 2899  3945  3966  3990  4017  4044  4130  4130  4080  4018  4040  4023  3986  3982  3966  3984  4035  4099  4152  4178  4175  4077
    +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +     +
```

********** MESOPAC **********

| | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2324 | 2600 | 4130 | 4130 | 4130 | 4006 | 4035 | 4065 | 4092 | 4114 | 4120 | 4083 | 4042 | 4000 | 3982 | 4048 | 4103 | 4168 | 4218 | 4278 | 4284 | 4198 |
| 2186 | 2483 | 2799 | 4130 | 3966 | 3994 | 4027 | 4062 | 4095 | 4121 | 4130 | 4122 | 4109 | 4101 | 4112 | 4233 | 4262 | 4297 | 4276 | 4265 | 4274 | 4225 |
| 2031 | 2343 | 2682 | 3157 | 3944 | 3971 | 4004 | 4043 | 4082 | 4114 | 4130 | 4116 | 4098 | 4087 | 4194 | 4237 | 4269 | 4280 | 4284 | 4271 | 4282 | 4235 |
| 1865 | 2187 | 2813 | 3086 | 3912 | 3934 | 3964 | 4000 | 4039 | 4078 | 4091 | 4084 | 4067 | 4149 | 4194 | 4244 | 4283 | 4299 | 4324 | 4311 | 4324 | 4250 |
| 917 | 2402 | 2722 | 3011 | 3255 | 3885 | 3903 | 3928 | 3957 | 3983 | 4012 | 4012 | 4094 | 4134 | 4192 | 4256 | 4309 | 4341 | 4354 | 4404 | 4438 | 4477 |
| 914 | 2296 | 2636 | 2939 | 3189 | 3826 | 3828 | 3832 | 3839 | 3848 | 3886 | 3991 | 4038 | 4104 | 4187 | 4275 | 4354 | 4413 | 4453 | 4481 | 4612 | 4638 |

********** MESOPAC **********

2001 1898 1800 1717

2212 2108 1994 1881

2469 2368 2237 2082

2764 2674 2528 2329

3028 3010 2861 2625

3308 3292 3207 2954

3646 3577 3512 3267

3772 3803 3735 3583

3845 3861 3800 3664

3828 3825 3770 3661

3773 3804 3672 3539

3693 3736 3746 3428

3682 3725 3680 3418

3662 3704 3478 3397

3678 3447 3402 3299

3472 3426 3475 3221

3522 3439 3436 3263

3606 3609 3423 3208

3840 3661 3436 3177

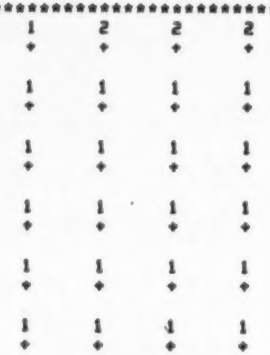
3932 3708 3409 3065

| | | | |
|---|---|---|---|
| 4007 | 3779 | 3466 | 3101 |
| + | + | + | + |
| 4141 | 3984 | 3743 | 3143 |
| + | + | + | + |
| 4165 | 4027 | 3809 | 3513 |
| + | + | + | + |
| 4192 | 4074 | 3883 | 3621 |
| + | + | + | + |
| 4251 | 4147 | 3979 | 3749 |
| + | + | + | + |
| 4366 | 4262 | 4106 | 3898 |
| + | + | + | + |

```
********** MESOPAC **********
STABILITY FIELD FOR  0 166 78 (HOUR,DAY,YEAR)
FIELD IN UNITS OF 10** 0
 2+ 2+ 2+ 2+ -+ -+ -+ -+ -+ -+ -+ -+ -+ -+ -+ -+ -+ -+ -+ -+ -+ -+
 2+ 2+ 2+ 2+ -+ -+ -+ -+ -+ -+ -+ -+ -+ -+ -+ -+ -+ -+ -+ -+ -+ -+
 2+ 2+ 2+ 2+ -+ -+ -+ -+ -+ -+ -+ -+ -+ -+ -+ -+ -+ -+ -+ -+ -+ -+
 2+ 2+ 2+ 2+ 2+ -+ -+ -+ -+ -+ -+ -+ -+ -+ -+ -+ -+ -+ -+ -+ -+ -+
 2+ 2+ 2+ 2+ 2+ 2+ 2+ 2+ 2+ 2+ 2+ 2+ -+ 2+ -+ -+ 2+ 2+ 2+ 2+
 2+ 2+ 2+ 2+ 2+ 2+ 2+ 2+ 2+ 2+ 2+ 2+ 2+ 2+ 2+ 2
```

MESOPAC
3 3 3 3 3 3 2 2 3 3 3 2 2 2 2 2 2 1 1 1 1 1
3 3 3 3 3 3 2 2 2 3 3 2 2 2 2 2 2 1 1 1 1 1
3 3 3 3 3 3 2 2 2 2 2 2 2 2 2 2 2 1 1 1 1 1
3 3 3 3 3 3 2 2 2 2 2 2 2 2 2 2 1 1 1 1 1 1
4 3 3 3 3 3 3 2 2 2 2 2 2 2 2 2 2 1 1 1 1 1 1
4 3 3 3 3 2 2 2 2 2 2 2 2 2 2 2 1 1 1 1 1 1 1

```
********** MESOPAC **********
2+  2+  2+  2+  -+  -+  -+  -+  -+  -+  -+  -+  -+  -+  -+  -+  -+  -+  -+  -+  2+
2+  2+  2+  2+  -+  -+  -+  -+  -+  -+  -+  -+  -+  -+  -+  -+  -+  -+  -+  -+  2+
2+  2+  2+  2+  -+  -+  -+  -+  -+  -+  -+  -+  -+  -+  -+  -+  -+  -+  -+  -+  2+
2+  2+  2+  2+  -+  -+  -+  -+  -+  -+  -+  -+  -+  -+  -+  -+  -+  -+  -+  -+  -+
```


1 2 2 2
1 1 1 1
1 1 1 1
1 1 1 1
1 1 1 1
1 1 1 1

# APPENDIX B

## TEST CASE MESOGRID OUTPUT

```
&MODEL
LPLUME=F,LPUFF=F,LGRID=T,LPAC=F,LFILE=F
&END
&CONTR
DTIME=  1.00000000    ,MTFREQ=          1,IAVG=         24,NADVTS=         72
&END
&GRID
IELMET=         26,JELMET=         26,DELTMT=  40000.0000    ,IASTAR=          1,IASTOP=         26,JASTAR=          1,JASTOP=
        26,ISASTR=          1,JSASTR=          1,ISASTP=         40,JSASTP=         40,MESHDN=          1
&END
&METD
METSRT=    7816500,METCOD=       1003,LSENSE=F
&END
&GRIDY
INVL=          3,CREFLT=  1.00000000    ,CEPSC=  .999999944E-10,CBOUND=  .0           ,  .0           ,  .0           ,
  .0           ,  .0           ,  .0           ,  .0           ,  .0           ,  .0           ,  .0           ,  .0           ,
  .0           ,  .0           ,  .0           ,  .0           ,  .0           ,  .0           ,  .0           ,  .0           ,
  .0           ,  .0           ,  .0           ,  .0           ,  .0           ,  .0           ,  .0           ,  .0           ,
  .0           ,  500.000000   ,  1500.00000   ,  4000.00000   ,NPTS=       9999,LREFLB=          0,MODRFL=          2,NOSPEC=
        1,LPACK=F,BACK2=  .0          ,BACK4=  .0          ,NPKZ=       9999
&END
&REMOV
CONVFR=  .199999996E-01,LUCAY=T,EXTNCT= -.5560000032E-05,LDEPOT=T,DEPVEL=  .100000016E-01,  .999999931E-03,LWASH=F,WASHOT=
  .0           ,  .0
&END
&OUTPT
LECHO=T,LPRINT=T,IPRINF=         24,LEXACT=F,LSAVE=F,ISAVEF=         24
&END
&SOURC
NSOURC=         10,LMISS=F,LFLUX=F,STAKHT=  236.000000    ,  152.000000    ,  152.000000    ,  152.000000    ,  183.000000    ,
  229.000000    ,  76.1999969    ,  183.000000    ,  175.000000    ,  152.000000    ,XXSTAK=  8.80000019    ,  23.3999939    ,
  17.1999969    ,  23.6999969    ,  13.5000000    ,  10.0000000    ,  8.00000000    ,  9.69999981    ,  .899999976    ,
  1.50000000    ,YYSTAK=  8.80000019    ,  14.0000000    ,  18.8999939    ,  13.0000000    ,  1.19999981    ,  13.1000004    ,
  19.5000000    ,  15.1999998    ,  8.00000000    ,  4.10000038    ,EMISS=  2560.00000    ,  .0           ,  343.800049    ,
  .0           ,  633.399902    ,  .0           ,  488.000000    ,  .0           ,  53.6999969    ,  .0           ,
  320.000000    ,  .0           ,  146.899994    ,  .0           ,  1310.80005    ,  .0           ,  268.800049    ,
  .0           ,  1011.00000    ,  .0           ,ECYCLE=  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,
  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,
  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,
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  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,
  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,
  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,
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  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,
  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,
  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,
  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,
  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,
  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,
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  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,
  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,
  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,
  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,
  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,
  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,
  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,
  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,
  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,
  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,
  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,
  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,
  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,
  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,
```

B-1

```
 1.00000000 , 1.00000000 , 1.00000000 , 1.00000000 , 1.00000000 , 1.00000000 , 1.00000000 ,
```

********** MESOGRID **********

24.0-HOUR CONCENTRATION (GRAMS/CUBIC METER) ENDING 0 166 78 (HOUR,DAY,YEAR) FOR
POLLUTANT 1: SULFUR DIOXIDE

THERE FOLLOWS 1 TABLE(S):

1) A 4 PAGE GRID OF CONCENTRATIONS, EXPRESSED IN INTEGER UNITS OF AN APPROPRIATE EXPONENT
PAGE 1: NW CORNER, PAGE 2: SW CORNER, PAGE 3: NE CORNER, PAGE 4: SE CORNER

B-3

TABLE 1 POLLUTANT 1 24.0 HOUR AVERAGE ENDING MESOGRID 0 166 78 (HOUR,DAY,YEAR) FIELD IN UNITS OF 10** -8

| | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 4 | 6 | 5 | 3 | 1 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 4 | 7 | 8 | 6 | 3 | 1 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 5 | 10 | 10 | 6 | 2 | 0 | 0 | 0 | 0 | 1 | 2 | 3 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 5 | 13 | 13 | 6 | 2 | 1 | 2 | 2 | 4 | 7 | 12 | 12 | 9 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 17 | 19 | 6 | 2 | 4 | 6 | 8 | 13 | 24 | 36 | 46 | 44 | 31 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 16 | 30 | 8 | 2 | 6 | 12 | 19 | 38 | 54 | 87 | 164 | 138 | 92 | 62 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 47 | 10 | 2 | 6 | 18 | 41 | 76 | 83 | 62 | 221 | 120 | 51 | 28 | 15 |
| 0 | 0 | 0 | 0 | 0 | 0 | 1 | 3 | 4 | 3 | 3 | 20 | 72 | 119 | 101 | 66 | 29 | 11 | 9 | 6 | 3 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 3 | 5 | 4 | 2 | 11 | 103 | 165 | 102 | 43 | 15 | 8 | 9 | 12 | 7 | 1 | 0 |
| 0 | 0 | 0 | 0 | 0 | 2 | 6 | 6 | 3 | 3 | 90 | 221 | 91 | 23 | 10 | 8 | 12 | 20 | 27 | 26 | 7 | 0 |
| 0 | 0 | 0 | 0 | 1 | 7 | 9 | 4 | 3 | 6 | 268 | 81 | 19 | 14 | 14 | 21 | 34 | 50 | 54 | 44 | 11 | 0 |
| 0 | 0 | 0 | 0 | 5 | 12 | 6 | 2 | 6 | 10 | 18 | 24 | 20 | 25 | 36 | 49 | 62 | 65 | 52 | 28 | 6 | 0 |
| 0 | 0 | 0 | 3 | 14 | 11 | 2 | 5 | 12 | 14 | 25 | 26 | 39 | 53 | 60 | 59 | 52 | 39 | 20 | 6 | 0 | 0 |
| 0 | 0 | 1 | 13 | 20 | 4 | 3 | 12 | 18 | 15 | 21 | 54 | 72 | 64 | 49 | 34 | 17 | 6 | 1 | 0 | 0 | 0 |
| 0 | 0 | 8 | 31 | 10 | 2 | 11 | 21 | 19 | 15 | 67 | 92 | 57 | 29 | 11 | 3 | 1 | 0 | 0 | 0 | 0 | 0 |
| 0 | 2 | 38 | 27 | 2 | 9 | 22 | 22 | 12 | 53 | 123 | 44 | 9 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 26 | 55 | 5 | 5 | 23 | 26 | 14 | 2 | 105 | 38 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 82 | 14 | 2 | 21 | 31 | 17 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 17 | 38 | 24 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 11 | 42 | 30 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

MESOGRID

| | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 7 | 45 | 34 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 35 | 21 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 2 | 1 | 1 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 13 | 14 | 10 | 6 | 4 | 2 | 1 | 1 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 18 | 11 | 3 | 1 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

B-5

********** MESOGRID **********

| | | | |
|---|---|---|---|
| 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 |
| 2 | 0 | 0 | 0 |
| 5 | 1 | 1 | 1 |
| 17 | 10 | 7 | 5 |
| 47 | 35 | 27 | 18 |
| 11 | 8 | 6 | 4 |
| 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 |
| 0 | 13 | 20 | 11 |
| 0 | 139 | 128 | 96 |
| 0 | 1 | 109 | 131 |
| 0 | 0 | 1 | 4 |
| 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 |

********** MESOGRID **********

********** MESOGRID **********

24.0-HOUR CONCENTRATION (GRAMS/CUBIC METER) ENDING 0 166 78 (HOUR,DAY,YEAR) FOR
POLLUTANT 2: SULFATES

THERE FOLLOWS 1 TABLE(S):

1) A 4 PAGE GRID OF CONCENTRATIONS, EXPRESSED IN INTEGER UNITS OF AN APPROPRIATE EXPONENT
PAGE 1: NW CORNER, PAGE 2: SW CORNER, PAGE 3: NE CORNER, PAGE 4: SE CORNER

********** MESOGRID **********

TABLE 1 POLLUTANT 2 24.0 HOUR AVERAGE ENDING 0 166 78 (HOUR,DAY,YEAR)

GRIDDED TABLES NOT PRINTED SINCE ALL CHIS ARE ZERO

********** MESOGRID **********

24.0-HOUR CONCENTRATION (GRAMS/CUBIC METER) ENDING 0 167 78 (HOUR,DAY,YEAR) FOR
POLLUTANT 1: SULFUR DIOXIDE

THERE FOLLOWS 1 TABLE(S):

1) A 4 PAGE GRID OF CONCENTRATIONS, EXPRESSED IN INTEGER UNITS OF AN APPROPRIATE EXPONENT
PAGE 1: NW CORNER, PAGE 2: SW CORNER, PAGE 3: NE CORNER, PAGE 4: SE CORNER

********** MESOGRID **********

TABLE 1 POLLUTANT 1 24.0 HOUR AVERAGE ENDING 0 167 78 (HOUR,DAY,YEAR) FIELD IN UNITS OF 10** -8

| | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 9 | 12 | 9 | 5 | 3 | 4 | 8 | 17 | 26 | 32 | 34 | 34 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 7 | 14 | 11 | 5 | 4 | 8 | 16 | 26 | 35 | 39 | 36 | 33 | 32 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 3 | 13 | 15 | 6 | 5 | 13 | 24 | 35 | 41 | 43 | 38 | 33 | 35 | 37 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 6 | 19 | 12 | 5 | 13 | 27 | 37 | 42 | 41 | 35 | 31 | 40 | 52 | 53 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 12 | 23 | 6 | 8 | 24 | 37 | 42 | 39 | 32 | 26 | 60 | 96 | 91 | 66 |
| 0 | 0 | 0 | 0 | 0 | 0 | 1 | 3 | 24 | 18 | 4 | 14 | 33 | 44 | 43 | 33 | 25 | 77 | 177 | 123 | 74 | 49 |
| 0 | 0 | 0 | 0 | 0 | 0 | 2 | 4 | 37 | 7 | 6 | 23 | 45 | 51 | 39 | 28 | 27 | 181 | 115 | 58 | 47 | 37 |
| 0 | 0 | 0 | 0 | 0 | 1 | 4 | 4 | 3 | 5 | 9 | 36 | 60 | 48 | 33 | 32 | 42 | 56 | 65 | 64 | 51 | 32 |
| 0 | 0 | 0 | 0 | 0 | 2 | 5 | 4 | 4 | 6 | 16 | 63 | 62 | 34 | 35 | 45 | 61 | 69 | 64 | 56 | 41 | 17 |
| 0 | 0 | 0 | 0 | 1 | 5 | 7 | 4 | 5 | 7 | 42 | 77 | 44 | 39 | 49 | 61 | 68 | 60 | 42 | 27 | 17 | 4 |
| 0 | 0 | 0 | 0 | 3 | 9 | 8 | 5 | 6 | 9 | 69 | 45 | 40 | 55 | 64 | 67 | 57 | 32 | 12 | 4 | 2 | 0 |
| 0 | 0 | 0 | 1 | 8 | 13 | 7 | 5 | 8 | 12 | 21 | 39 | 57 | 73 | 74 | 59 | 30 | 7 | 1 | 0 | 0 | 0 |
| 0 | 0 | 0 | 4 | 17 | 14 | 5 | 5 | 11 | 16 | 33 | 50 | 80 | 87 | 65 | 29 | 5 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 15 | 24 | 10 | 4 | 9 | 17 | 21 | 31 | 82 | 105 | 72 | 25 | 3 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 8 | 31 | 20 | 4 | 6 | 16 | 25 | 24 | 71 | 124 | 78 | 21 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 3 | 35 | 36 | 7 | 3 | 14 | 27 | 27 | 52 | 133 | 77 | 14 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 28 | 58 | 11 | 1 | 12 | 29 | 31 | 20 | 104 | 50 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 70 | 16 | 0 | 9 | 29 | 35 | 22 | 7 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 6 | 31 | 41 | 23 | 6 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 4 | 31 | 44 | 22 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |

MESOGRID

| | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 5 | 35 | 43 | 16 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 3 | 2 | 2 | 1 |
| 0 | 31 | 24 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 4 | 6 | 3 | 2 | 2 | 1 | |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 5 | 7 | 4 | 2 | 1 | 1 | 1 | |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 8 | 7 | 3 | 1 | 0 | 0 | 0 | 0 | |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7 | 4 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |

********** MESOGRID **********

| | | | |
|---|---|---|---|
| 34 | 30 | 20 | 12 |
| 31 | 23 | 15 | 12 |
| 34 | 26 | 21 | 22 |
| 44 | 36 | 31 | 30 |
| 49 | 37 | 31 | 28 |
| 35 | 27 | 21 | 19 |
| 27 | 19 | 13 | 9 |
| 19 | 11 | 6 | 5 |
| 9 | 5 | 7 | 12 |
| 2 | 16 | 30 | 29 |
| 1 | 55 | 70 | 52 |
| 0 | 125 | 83 | 76 |
| 0 | 0 | 85 | 65 |
| 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 |
| 1 | 1 | 1 | 1 |
| 1 | 1 | 1 | 1 |

********** MESOGRID **********

| | | | |
|---|---|---|---|
| 1 | 1 | 1 | 1 |
| 1 | 1 | 1 | 0 |
| 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 |

********** MESOGRID **********

24.0-HOUR CONCENTRATION (GRAMS/CUBIC METER) ENDING 0 167 78 (HOUR,DAY,YEAR) FOR
POLLUTANT 2: SULFATES

THERE FOLLOWS 1 TABLE(S):

1) A 4 PAGE GRID OF CONCENTRATIONS, EXPRESSED IN INTEGER UNITS OF AN APPROPRIATE EXPONENT
PAGE 1: NW CORNER, PAGE 2: SW CORNER, PAGE 3: NE CORNER, PAGE 4: SE CORNER

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********** MESOGRID **********
TABLE 1 POLLUTANT 2 24.0 HOUR AVERAGE ENDING 0 167 78 (HOUR,DAY,YEAR)

GRIDDED TABLES NOT PRINTED SINCE ALL CHIS ARE ZERO

********** MESOGRID **********

24.0-HOUR CONCENTRATION (GRAMS/CUBIC METER) ENDING 0 168 78 (HOUR,DAY,YEAR) FOR
POLLUTANT 1: SULFUR DIOXIDE

THERE FOLLOWS 1 TABLE(S):

1) A 4 PAGE GRID OF CONCENTRATIONS, EXPRESSED IN INTEGER UNITS OF AN APPROPRIATE EXPONENT
PAGE 1: NW CORNER, PAGE 2: SW CORNER, PAGE 3: NE CORNER, PAGE 4: SE CORNER

********** MESOGRID **********

TABLE 1 POLLUTANT 1 24.0 HOUR AVERAGE ENDING 0 168 78 (HOUR,DAY,YEAR) FIELD IN UNITS OF 10** -8

| | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 8 | 7 | 3 | 2 | 1 | 2 | 5 | 11 | 15 | 17 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 10 | 9 | 4 | 2 | 2 | 3 | 8 | 14 | 22 | 22 | 19 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 11 | 13 | 5 | 3 | 2 | 5 | 14 | 27 | 33 | 30 | 18 | 12 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 20 | 8 | 3 | 3 | 7 | 23 | 38 | 44 | 33 | 24 | 28 | 32 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 27 | 16 | 5 | 4 | 9 | 32 | 53 | 54 | 36 | 46 | 94 | 113 | 106 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 20 | 33 | 9 | 5 | 7 | 39 | 74 | 67 | 42 | 63 | 156 | 157 | 107 | 70 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 41 | 13 | 4 | 4 | 39 | 100 | 87 | 47 | 34 | 150 | 99 | 40 | 26 | 25 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 4 | 4 | 28 | 127 | 122 | 56 | 36 | 28 | 21 | 22 | 34 | 52 | 55 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 5 | 12 | 139 | 182 | 73 | 35 | 23 | 19 | 23 | 35 | 58 | 86 | 81 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 6 | 6 | 101 | 259 | 90 | 27 | 16 | 15 | 24 | 36 | 50 | 80 | 106 | 89 |
| 0 | 0 | 0 | 0 | 0 | 0 | 1 | 6 | 7 | 4 | 245 | 83 | 15 | 11 | 13 | 24 | 37 | 51 | 69 | 85 | 84 | 53 |
| 0 | 0 | 0 | 0 | 0 | 1 | 6 | 9 | 6 | 3 | 4 | 10 | 11 | 11 | 25 | 42 | 58 | 68 | 70 | 63 | 51 | 25 |
| 0 | 0 | 0 | 0 | 0 | 6 | 11 | 8 | 4 | 2 | 11 | 7 | 8 | 27 | 53 | 71 | 69 | 56 | 40 | 26 | 15 | 7 |
| 0 | 0 | 0 | 0 | 6 | 15 | 12 | 6 | 3 | 1 | 1 | 7 | 37 | 76 | 88 | 67 | 43 | 23 | 11 | 5 | 2 | 1 |
| 0 | 0 | 0 | 6 | 20 | 16 | 7 | 2 | 1 | 1 | 12 | 61 | 109 | 97 | 55 | 27 | 11 | 4 | 1 | 0 | 0 | 0 |
| 0 | 0 | 9 | 31 | 21 | 7 | 1 | 0 | 1 | 22 | 109 | 126 | 79 | 34 | 13 | 4 | 1 | 0 | 0 | 0 | 0 | 0 |
| 0 | 11 | 47 | 24 | 5 | 0 | 0 | 2 | 13 | 112 | 89 | 42 | 16 | 5 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 58 | 20 | 1 | 0 | 0 | 6 | 24 | 37 | 34 | 21 | 9 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 3 | 18 | 39 | 42 | 30 | 12 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 8 | 34 | 49 | 39 | 18 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

********** MESOGRID **********

| | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 3 | 22 | 44 | 43 | 22 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 36 | 34 | 18 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 2 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 3 | 3 | 3 | 2 | 2 | 2 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 2 | 1 | 1 | 1 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

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********** MESOGRID **********

| | | | |
|---|---|---|---|
| 16 | 15 | 13 | 13 |
| 14 | 11 | 10 | 9 |
| 9 | 7 | 6 | 6 |
| 29 | 21 | 17 | 12 |
| 82 | 57 | 42 | 31 |
| 52 | 42 | 39 | 33 |
| 16 | 10 | 9 | 8 |
| 29 | 17 | 14 | 12 |
| 37 | 23 | 20 | 17 |
| 32 | 17 | 16 | 14 |
| 13 | 3 | 3 | 3 |
| 4 | 85 | 132 | 108 |
| 1 | 0 | 82 | 101 |
| 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 |

********** MESOGRID **********

| | | | |
|---|---|---|---|
| 0 | 0 | 0 | 0 |
| 1 | 1 | 1 | 1 |
| 1 | 1 | 1 | 1 |
| 2 | 1 | 1 | 1 |
| 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 |

********** MESOGRID **********

24.0-HOUR CONCENTRATION (GRAMS/CUBIC METER) ENDING 0 168 78 (HOUR,DAY,YEAR) FOR
POLLUTANT 2: SULFATES

THERE FOLLOWS 1 TABLE(S):

1) A 4 PAGE GRID OF CONCENTRATIONS, EXPRESSED IN INTEGER UNITS OF AN APPROPRIATE EXPONENT
PAGE 1: NW CORNER, PAGE 2: SW CORNER, PAGE 3: NE CORNER, PAGE 4: SE CORNER

********** MESOGRID **********

TABLE 1 POLLUTANT 2 24.0 HOUR AVERAGE ENDING 0 168 78 (HOUR,DAY,YEAR)

GRIDDED TABLES NOT PRINTED SINCE ALL CHIS ARE ZERO

# APPENDIX C

## TEST CASE NAMELIST FILE

```
 INUMB    DATFLD        MODEL      YR/DAY/HR     NGRIDS      IAVG      ISAVEF     ISAFE     IBEGIN     ISTUP     ICHECK
-------------------------------------------------------------------------------------------------------------------------

   1   12 FEB 1979     MESOPLUM    78/165/ 0        3         24         24         1         2         4         1

 ********************************************************************************************************************************

 &MODEL
 LPLUME=T,LPUFF=F,LGRID=F,LPAC=F
 &END
 &CONTR
 DTIME=  1.00000000    ,MTFREQ=          1,IAVG=         24,NADVTS=         72
 &END
 &GRID
 IELMET=         26,JELMET=         26,DELTMT=  40000.0000    ,IASTAR=          1,IASTOP=         26,JASTAR=          1,JASTOP=
        26,ISASTR=          1,JSASTR=          1,ISASTP=         26,JSASTP=         26,MESHDN=          1
 &END
 &SIGMA
 AY=  .329999983    ,  .220000029    ,  .170000017    ,  .120000005    ,  .860000253E-01,  .570000000E-01,BY= -.100000024    ,
  -.100000024    , -.100000024    , -.100000024    , -.100000024    , -.100000024    ,AZ=  .479999930E-03,  .630000234E-01,
   .100000024    ,  .329999983    ,  .410000026    ,  .319999993    ,BZ=  1.10000038    ,  .899999738E-01, -.899999738E-01,
  -.420000017    , -.529999971    , -.579999983
 &END
 &METD
 METSRT=    7816500,METCOD=       1003,LSENSE=F
 &END
 &PLUM1
 MAXSEG=        100,LLID=T,LSTAB=T,LDEPTH=T,MSTABV=          4,         4,         4,         4,         4,         4,
          4,         4,         4,         4,         4,         4,         4,         4,         4,         4,         4,
          4,         4,         4,         4,         4,         4,         4,         4,         4,         4,         4,
  1000.00000    ,  1000.00000    ,  1000.00000    ,  1000.00000    ,  1000.00000    ,  1000.00000    ,HMMV=  1000.00000    ,  1000.00000    ,
  1000.00000    ,  1000.00000    ,  1000.00000    ,  1000.00000    ,  1000.00000    ,  1000.00000    ,  1000.00000    ,  1000.00000    ,
  1000.00000    ,  1000.00000    ,  1000.00000    ,  1000.00000    ,  1000.00000    ,  1000.00000    ,  1000.00000    ,  1000.00000    ,
  1000.00000
 &END
 &PLUM2
 NME=          0,XMES=  .0          ,  .0          ,  .0          ,  .0          ,  .0          ,  .0          ,  .0          ,
   .0          ,  .0          ,  .0          ,  .0          ,  .0          ,YRES=  .0          ,  .0          ,  .0          ,
   .0          ,  .0          ,  .0          ,  .0          ,  .0          ,  .0          ,  .0          ,
 &END
 &REMOV
 CONVFK=  .199999996E-01,LUCAY=T,EXTNCT= -.556000032E-05,LDEPOT=T,DEPVEL=  .100000016E-01,  .999999931E-03,LWASH=F,WASHOT=
   .0          ,  .0
 &END
 &OUTPT
 LECHO=T,LPRINT=T,IPRINF=         24,LEXACT=F,LSAVE=T,ISAVEF=         24
 &END
 &SOURC
 NSOURC=        10,STKHGT=  236.000000    ,  152.000000    ,  152.000000    ,  152.000000    ,  183.000000    ,  229.000000    ,
   76.1999969    ,  183.000000    ,  175.000000    ,  152.000000    ,XXSTAK=  8.80000019    ,  23.3999939    ,  17.1999969    ,
   23.6999969    ,  13.5000000    ,  10.0000000    ,  8.00000000    ,  9.69999981    ,  .899999976    ,  1.50000000    ,YYSTAK=
    8.80000019    ,  14.0000000    ,  18.6999939    ,  13.0000000    ,  1.19999981    ,  13.1000004    ,  19.5000000    ,
   15.1999998    ,  6.00000000    ,  4.10000038    ,EMISS=  2560.00000    ,  .0          ,  343.800049    ,  .0          ,
  633.399902    ,  .0          ,  488.000000    ,  .0          ,  53.6999969    ,  .0          ,  320.000000    ,
  .0          ,  146.899994    ,  .0          ,  1310.80005    ,  .0          ,  268.800049    ,  .0          ,
 1011.00000    ,  .0          ,LMISS=F,ECYCLE=  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,
 1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,
 1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,
 1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,
 1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,
 1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,
```

```
1.00000000 , 1.00000000 , 1.00000000 , 1.00000000 , 1.00000000 , 1.00000000 , 1.00000000 ,
```

```
  1.00000000     ,  1.00000000     ,  1.00000000     ,  1.00000000
&END
```

**********

```
      INUMM    DATFLD        MODEL      YR/DAY/HR     NGRIDS      IAVG      ISAVEF     ISAFE     IBEGIN     ISTOP     ICHECK
      ----------------------------------------------------------------------------------------------------------------------

        2   12 FEB 1979     MESOPUFF    78/165/ 0        3         24         24         5         6         8         1

*******************************************************************************************************************************

&MODEL
LPLUME=F,LPUFF=T,LGRID=F,LPAC=F
&END
&CONTM
DTIME=  1.00000000    ,MTIMEU=          1,IAVG=         24,NADVTS=         72
&END
&GRID
IELMET=         26,JELMET=         26,DELTMT=  40000.0000    ,IASTAR=          1,IASTOP=         26,JASTAR=          1,JASTOP=
        26,ISASTM=          1,JSASTM=          1,ISASTP=         26,JSASTP=         26,MESHDN=          1
&END
&SIGMA
AY=  .329999983    ,  .220000029    ,  .170000017    ,  .120000005    ,  .860000253E-01,  .570000000E-01,BY= -.100000024    ,
 -.100000024    , -.100000024    , -.100000024    , -.100000024    , -.100000024    ,AZ=  .479999930E-03,  .630000234E-01,
  .100000024    ,  .329999983    ,  .410000026    ,  .319999993    ,HZ=  1.10000038    ,  .899999738E-01, -.899999738E-01,
 -.420000017    , -.529999971    , -.579999983
&END
&METD
METSTB=    7816500,METCOD=       1003,LSENSE=F
&END
&PUFF1
NPUFTS=          0,NSAMAU=          1,LVARSA=T,MAXSAM=        100
&END
&PUFF2
IPFLIM=        400,CHIMIN=  .0           ,  .0           ,NSIGMA=          3,LANUAL=F,LUFORM=T
&END
&REMOV
CONVFM=  .149999996E-01,LUCAY=T,EXTINCT= -.556000032E-05,LDEPOT=T,DEPVEL=  .100000016E-01,  .999999931E-03,LWASH=F,WASHUT=
  .0            ,  .0
&END
&OUTPT
LECHO=T,LPRINT=T,IPRINT=         24,LEXACT=F,LSAVE=T,ISAVEF=         24
&END
&SOURC
NSOURC=         10,STAKHT=  236.000000    ,  152.000000    ,  152.000000    ,  152.000000    ,  183.000000    ,  229.000000    ,
  76.1999969    ,  183.000000    ,  175.000000    ,  152.000000    ,XXSTAK=  8.80000019    ,  23.3999939    ,  17.1999969    ,
  23.6999969    ,  13.5000000    ,  10.0000000    ,  8.00000000    ,  9.69999981    ,  .899999976    ,  1.50000000    ,YYSTAK=
  8.80000019    ,  14.0000000    ,  18.8999939    ,  13.0000000    ,  1.19999981    ,  13.1000004    ,  19.5000000    ,
  15.1999998    ,  8.00000000    ,  4.10000038    ,EMISS=  2560.00000    ,  .0            ,  343.800049    ,  .0            ,
  633.399902    ,  .0            ,  488.000000    ,  .0            ,  53.6999969    ,  .0            ,  320.000000    ,
  .0            ,  146.899994    ,  .0            ,  1310.80005    ,  .0            ,  268.800049    ,  .0            ,
  1011.00000    ,  .0            ,LMISS=F,ECYCLE=  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,
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```

```
 1.00000000 , 1.00000000 , 1.00000000 , 1.00000000 , 1.00000000 , 1.00000000 , 1.00000000 ,
```

```
 INUMB    DATFLD        MODEL      YR/DAY/HR     NGRIDS      IAVG      ISAVEF     ISAFE     IBEGIN     ISTOP     ICHECK
-------------------------------------------------------------------------------------------------------------------------

   5   12 FEB 1974     MESOGRID    78/165/ 0        3         24         24         9         10         12         1

*************************************************************************************************************************

 &MODEL
 LPLUME=F,LPUFF=F,LGRID=T,LPAC=F
 &END
 &CONTR
 DTIME=  1.00000000    ,MTFREQ=          1,IAVG=         24,NADVTS=         72
 &END
 &GRID
 IELMET=         26,JELMET=         26,DELTMT=  40000.0000    ,IASTAR=          1,IASTOP=         26,JASTAR=          1,JASTOP=
        26,ISASTR=          1,JSASTR=          1,ISASTP=         26,JSASTP=         26,MESHDN=          1
 &END
 &METD
 METSWI=    7816500,METCOD=       1003,LSENSE=F
 &END
 &GRIDY
 INVL=          3,CREFLT=  1.00000000    ,CREFLB=  1.00000000    ,CEPSC=  .999999944E-10,CBOUND=  .0          ,  .0          ,
   .0           ,  .0           ,  .0           ,  .0           ,  .0           ,  .0           ,  .0           ,  .0           ,
   .0           ,  .0           ,  .0           ,  .0           ,  .0           ,  .0           ,  .0           ,  .0           ,
   .0           ,  .0           ,  .0           ,  .0           ,  .0           ,  .0           ,  .0           ,  .0           ,
   .0          ,CZ=  .0          ,  500.000000   ,  1500.00000   ,  4000.00000   ,NPTS=       9999,LREFLB=          0,MOURFL=
        2,NOSPEC=          1,LBACK=F,BACK2=  .0          ,BACK4=  .0          ,NPKZ=       9999
 &END
 &REMOV
 CONVFK=  .199999996E-01,LUCAY=T,EXTINCT= -.556000032E-05,LDEPOT=T,DEPVEL=  .100000016E-01,  .999999931E-03,LWASH=F,AASHUT=
   .0           ,  .0
 &END
 &OUTPT
 LECHO=T,LPRINT=T,IPRINF=         24,LEXACT=F,LSAVE=T,ISAVEF=         24
 &END
 &SOURC
 NSOURC=         10,STKHT=  236.000000    ,  152.000000    ,  152.000000    ,  152.000000    ,  183.000000    ,  229.000000    ,
   76.1999969    ,  185.000000    ,  175.000000    ,  152.000000    ,XXSTAK=  8.80000019    ,  23.3999939    ,  17.1999969    ,
   25.6999969    ,  13.5000000    ,  10.0000000    ,  8.00000000    ,  9.69999981    ,  .899999976    ,  1.50000000    ,YYSTAK=
   8.80000019    ,  14.0000000    ,  18.8999939    ,  13.0000000    ,  1.19999981    ,  13.1000004    ,  19.5000000    ,
   15.1999998    ,  8.00000000    ,  4.10000038    ,EMISS=  2560.00000    ,  .0          ,  343.800049    ,  .0          ,
   653.399902    ,  .0          ,  488.000000    ,  .0          ,  53.6999969    ,  .0          ,  320.000000    ,
   .0            ,  146.899994    ,  .0          ,  1310.80005    ,  .0          ,  268.800049    ,  .0          ,
   1011.00000    ,  .0          ,LMISS=F,ECYCLE=  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,
   1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,  1.00000000    ,
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